metal finishing Journal

August, 1957 — AN INDUSTRIAL NEWSPAPERS PUBLICATION — Vol. 3, No. 32 (New Series)

Editor: JOHN HOOPER *Managing Editor:* ALASTAIR McLEOD, F.I.M. *Assistant Editor:* E. H. LLOYD, A.I.M., A.C.T.(Birm.)
Southern Area Manager: E. COLLIS *Northern Area Manager:* G. P. ELLIOTT *Scottish Area Manager:* T. H. SMITH
Western Area Manager: E. J. SWEETING *Eastern Area Manager:* ERIC PERRIN
Production Manager: R. J. LOVELL *Circulation Manager:* E. T. GRIFFITHS *Publisher:* H. J. DWYER

Official Organ of the
INSTITUTE OF VITREOUS ENAMELLERS

President:
C. R. WHEELER, C.B.E.
Chairman:
W. THOMAS
Secretary:
J. D. GARDOM
John Gardom & Co., Ripley, Derby
Telephone: Ripley 136

Published on the 15th day of each month by

INDUSTRIAL NEWSPAPERS LIMITED

Chairman and Joint Managing Director:
Barrington Hooper, C.B.E.
Joint Managing Director and Commercial Director:
F. Barrington Hooper, B.A.
Director:
F. R. Lewis
Director and Secretary:
E. G. Weston

JOHN ADAM HOUSE
17-19 JOHN ADAM STREET
ADELPHI, LONDON, W.C.2

Telephone: TRAfalgar 6171 (P.B.X.)
Telegrams: Zacatecas, Rand, London

Subscription Terms:
Home and Overseas 24*s.* per annum prepayable
Single copies 2*s.* (2*s.* 4*d.* *post free*)

THIS JOURNAL IS DEVOTED TO THE SCIENCE AND TECHNOLOGY OF PAINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, GALVANIZING, ANODIZING, METAL SPRAYING & ALL METAL FINISHING PROCESSES. THE EDITOR IS PREPARED TO CONSIDER FOR PUBLICATION ANY ARTICLE COMING WITHIN THE PURVIEW OF "METAL FINISHING JOURNAL" AND ALL SUCH ARTICLES ACCEPTED WILL BE PAID FOR AT THE USUAL RATES.

Contents

PAGE

Stylish Tyrants **309**

Talking Points **310**
"Platelayer"

Some Problems in the Finishing of Zinc-alloy Die-castings **311**
J. Edwards, Ph.D., B.Sc.

Production and Applications of Aluminium Powders and Pastes (cont.) **317**

A Survey of Air Treatment Systems in Use in the Metal Finishing Industries (*Cont.*) **323**
Leo Walter, A.M.I.H.V.E., A.M.I.Plant E.

The Effect of Ceramic Coatings on Creep **326**

Current Mill Room Practice **327**
S. H. Ryder, B.Sc., A.R.I.C., A.I.M.

Tin Research Institute Celebrates "First Twenty-Five Years" **333**

An Examination of Concentration Differences in Lead-Fluoborate Plating Baths **335**

Finishing News Review **339**

Plant, Processes and Equipment **343**

B T P
TITANIUM OXIDE

The best grades for vitreous enamels

Giving—improved acid resistance and greater opacity, increased brightness and better gloss and gloss retention

B T P TITANIUM OXIDE is made in Britain by British Titan Products Company Limited the largest Titanium Oxide manufacturer outside the United States

Factories at Grimsby and Billingham and at Burnie, Tasmania

Agents in most principal countries

BRITISH TITAN PRODUCTS COMPANY LIMITED
COPPERGATE
YORK

STYLISH TYRANTS

IN the last few days the correspondence columns of one of our national newspapers have once again been sporting the sincerely irate, but not necessarily well-informed criticisms of private motor-car owners deprecating the early failure in service of the finish on certain parts of their car bodies. One correspondent went so far as to say that if only aluminium sheet were used throughout for the body-work, problems of corrosion and paint failure would not arise.

This sort of complaint is a hardy annual, and perhaps by its very repetition it has deafened the ears of those on whom it should make the maximum impact. The standard of performance of car-body finishes, both painted and plated, as well as of the finish of numerous other items of equipment in domestic use, is continually being compared to its detriment with that obtaining twenty years ago, but such comparisons are often unreal because they tend to be coloured by the unreliability of personal reminiscence.

In an entirely cursory attempt to assess the adequacy or otherwise of the foundation of these complaints, we spent an odd hour recently in a large car park populated by a wide variety of cars of all makes and vintages, where at the risk of being detained on a charge of loitering with intent, we took the opportunity of examining the condition of the finish of a very large, and presumably representative, sample.

Our findings, which presumably could be duplicated by anyone else with the necessary leisure and interest in the subject, were not very conclusive in deciding the issue between the quality of pre-war and post-war finishes, because of the manifest impossibility of finding samples of each finish which had been subjected to the same amount of service life. Nevertheless, certain general observations may be worthy of record. For example, a number of cars dating back to as early as 1934 were found still with their original paint coating which, in the great majority of cases, was still in surprisingly good condition, the chief defects being considerable loss of gloss and substantial chipping at corners and edges.

On post-war cars there was apparent a wide divergence in the amount of cleaning and care afforded to the body-work by the various owners. Where steps had been taken to remove dirt and to wax polish the finish, the amount of failure observed was very small indeed and what there was, could in almost every case, be attributed to bad functional styling.

Plating did not emerge so favourably from this casual survey as did paint, and blistering and peeling of nickel-chrome, particularly from the surface of zinc-alloy die-castings, was frequently observed. A number of instances were noted where presumably as a result of high local stress in the coating this had stripped locally and was curling back from the surface of the base metal. Significant in this connexion was the fact that the plating on many of the pre-war motor-cars showed more evidence of having been worn through than of having flaked or blistered.

One general conclusion, however, which appeared to be important in relation to the service performance of car-body finishes, and applies in the case of the finishes on many other pieces of equipment, is that there is still far too little attention being paid to finishing and corrosion-resistance requirements by those responsible for dictating style. If the stylists are in fact as omnipotent as we are sometimes led to believe, it is high time that they were toppled from their perch, or that they were subjected to an intensive course in finishing requirements; we would then perhaps see a reduction in the number of unnecessary moisture traps, inaccessible recesses and other bugbears of good finishing practice.

Talking Points by "PLATELAYER"

TOPICAL COMMENT FROM THE MAIN LINES AND SIDE LINES OF METAL FINISHING

SCIENCE IN THE SUNSHINE

ONE of the nicer results of the conversion of fine country mansions into research establishments is that it gives those who work in cities and factories an excuse for a pleasant day in the country on their Open Days, where one can combine technical edification with luncheon in a marquee in congenial society. This summer the weather has been very kind to Open Day goers. One of my favourite Open Day resorts is the Fulmer Research Institute which always has something of interest to show in a delightful location.

Although the Institute specializes in work on corrosion it was most disappointing to see how little of it was concerned with metal-finishing processes. In fact, a small exhibit dealing with the painting of electrogalvanized steel was all that could be seen. A number of interesting facts came to light during the day; one was that about half the work of the Institute is sponsored by the Government, nationalized industries, and corporations, and only about one-fifth by private industry. A very substantial proportion of the work of the Institute is also carried out on behalf of the United States Government, curiously enough. This is as it should be—it is much better that we should export science than scientists.

A MYSTERY OF NICKEL

MYSTERY Lake is the location of the new nickel mine in Manitoba which should, by 1960, increase the availability of nickel in the free world to some 270,000 tons per annum, or half as much again as the present figure. This is a formidable percentage, and fantastic as it may seem to those affected by the current shortage of this metal which is so essential in the plating industry, the problem of a possible nickel surplus is already exercising the minds of many people on the producing side. For the nickel shortage is probably not a serious one quantitatively—possibly supply is no more than 10 per cent. short of demand. But when a shortage of anything develops—even a small shortage—everything conspires to make it look much larger than, in fact, it is. Human nature being what it is, estimates of future requirements are exaggerated to suppliers, stocks are not revealed, multiple orders are placed, and so on in an effort to safeguard the future; it is a case of every man for himself.

The tremendous cost of opening up a new mine of this kind is realized when we read that the project is a result of ten years of work and the expenditure of around £3 million on exploration alone. Even this is probably chicken-feed as compared with what will have to be spent on towns, roads, railways, and so on before the mine begins to show a return.

So let us relax and possess ourselves in patience a little longer!

THE ROUGH AND THE SMOOTH

THERE is one law of nature which has become known in less refined technical circles as the Law of Sheer Cussedness. Essentially this boils down to the fact that if ever one tries to achieve a certain result everything will tend to prevent it being obtained consistently. As an example, platers have devoted a great deal of attention to obtaining a high degree of adhesion to deposits, but failures due to peeling plate are still common. Yet anyone who has tried to obtain non-adherent deposits in the manufacture of sheet metals by electrodeposition, or in electroforming processes, knows that in such cases good adhesion is obtained as often as not!

In the phosphating industry the same problem is arising as a result of the need for crystalline phosphate coatings for drawing and pressing operations. For years everybody has been concentrating on obtaining smooth, non-crystalline phosphate films to provide a good basis upon which to paint, but when phosphate coatings are used for metal drawing or pressing, the more crystalline the films are the better. Such films are proving surprisingly difficult to obtain consistently, however. One method recently patented is to include small amounts of nickel or cobalt salts in a chlorate-accelerated zinc-phosphate bath. A good deal of investigation is going on at the present time on what is likely to be a very big field of application of phosphate processes in the future.

CALLING THE TUNE

MY comments last month about BISRA have prompted a correspondent to express strongly the view that the Association should concern itself with fundamental research work rather than with what are really development projects.

As BISRA's research programme is substantially paid for and controlled by member firms, they are presumably getting what they want, and who can gainsay them?

Some Problems in THE FINISHING OF ZINC-ALLOY DIE-CASTINGS†

by J. EDWARDS, Ph.D., B.Sc.*

Introduction

FOR many years the British Non-Ferrous Metals Research Association has included among its members firms with a major interest in the chemical and electrochemical finishing of ferrous and non-ferrous materials. While day-to-day problems and requests for information on finishing zinc-alloy die castings have been referred to the Association for advice and attention, it is only recently that any systematic long-term work has been undertaken directly in this field. The purpose of this paper is to summarize previously published information on the topics under investigation, to indicate the lines being followed in the current experimental work and to comment, briefly—since useful results are only just beginning to emerge—on the progress so far achieved. It is hoped that it may be possible at some later date to prepare a further paper summarizing the results and conclusions of these investigations.

Processing Difficulties in Plating Zinc-alloy Die-castings—Process Blistering

The electroplating of zinc-alloy die castings presents certain special difficulties arising mainly from the following causes:—

(*a*) Zinc die-casting alloy is fairly readily attacked by some cleaning and plating solutions and care is therefore necessary to avoid spoiling the articles and contaminating the solutions.

(*b*) Unless casting conditions and fettling and polishing procedures are carefully chosen and maintained, the surface of the casting may be an unsound base for electroplated coatings.

(*c*) The complex shape of many castings makes it extremely difficult to apply coatings of reasonably uniform thickness and to prevent high-current-density "burning" at sharp projections.

In spite of these difficulties, adequate casting and plating procedures are available enabling zinc-alloy die castings to be satisfactorily plated on a very large scale. Rejections due to defective coatings are commoner, however, than in similar plating processes applied to steel or brass articles.

A characteristic defect of copper/nickel/chromium-plated zinc castings is "process" blistering, *i.e.*, blisters occurring during or immediately after plating. Such blisters vary a good deal in appearance and often seem to come and go without any change being deliberately made in the processing conditions. It is not surprising, therefore, to find that they have been attributed to a wide variety of causes.

Casting defects such as pores or laps in the surface of the article can give rise to blistering. They may trap electrolyte which attacks the basis metal and develops a gas pressure sufficient to raise a blister[1]. Such defects are often smeared over by buffing, but are sometimes opened up again during cleaning. A recent publication[2], however, claims that annealing at 210° C for one hour before polishing allows a more effective concealment of surface defects such as "cold-shot". Superficial porosity can sometimes however be completely removed by grinding on an emery wheel[3,4]; the outer dense "skin", so far as it can be distinguished as such, is often too thick to present any serious danger of its being penetrated in polishing.

Local non-adherence of the coating and consequent blistering can result from the presence of insoluble contaminants in processing solutions and from undue delays in the processing sequence. It has been reported that too high a *p*H in the copper plating bath[4, 5] and chromic-acid contamination of the bath[4] increase the tendency to blistering. Incomplete cleaning can also, of course, be responsible for blistering, but there have been many reports of blisters caused by "overcleaning", *i.e.*, the use of too prolonged or severe a treatment in an alkaline cleaning bath. There have been various attempts to explain the effect of overcleaning, as will be seen below.

* Head of Electrodeposition Section, The British Non-Ferrous Metals Research Association, London, N.W.1.

† A paper presented to the International Pressure Die Casting Conference, Paris, May, 1957.

Blistering which sometimes occurs when plated castings are stoved at temperatures up to 150° C (in enamelling for example) has been attributed to the formation of a brittle diffusion layer between the zinc base and the copper deposit. Anderson and Reinhard[6] examined microsections of blisters in which separation clearly occurred in this layer. They showed that the rate of diffusion is greater on unpolished than on polished surfaces and that it increases with increasing time of cleaning of the basis metal. They and Oplinger drastically reduced blistering after plating and lacquering by adopting milder cleaning procedures—shorter times, more dilute solutions and non-electrolytic or anodic instead of cathodic treatment.

Lewis[8] and Roberts[9] confirmed that overcleaning accelerates diffusion and suggested that activation by hydrogen might be the explanation. The latter author also confirmed that polishing the zinc alloy reduces the rate of diffusion.

The brittleness of the copper-zinc diffusion layer is not in itself a sufficient explanation of blistering, but it is contended that the layer is so weak as to be unable to withstand any pressure tending to lift the coating from the base. Some investigators seem to have assumed that diffusion can contribute to blistering even when the plated casting is not subjected to an elevated temperature for any length of time either in processing or in service. It is unlikely, however, that any appreciable diffusion takes place in such conditions.

An alternative explanation of the effect of overcleaning was proposed by Petrocelli and Phillips[1], who suggested that cathodic or non-electrolytic alkaline cleaning preferentially dissolves the aluminium-rich portions of the die-casting, so forming channels capable of trapping electrolyte.

Wernick, Symonds and Castell[10] concluded from their examination of large numbers of process blisters that a common cause of the defect was corrosion occurring between casting and polishing. They considered that small, corroded areas having liquid-retaining properties remained on the surface of the casting after the polishing treatment. Such areas could trap electrolyte during cleaning and plating and thus give rise to blistering.

Process blisters arising from all these causes can obviously be avoided to some extent by taking suitable precautions. Thus, the surface quality of die castings can often be improved by repositioning and sometimes enlarging gates, overflows and vents in the die. It is usually considered that freedom from surface flaws of various kinds is best attained by aiming at casting conditions giving a lightly "bloomed" surface. Surface imperfections can sometimes be removed in polishing, as mentioned earlier, but if they are deep the castings should be rejected. Careful polishing will also remove small corroded areas on the casting, such as those observed by Wernick, Symonds and Castell; these authors also recommend the provision of clean, dry storage conditions for raw castings and possibly the application of some temporary protective to avoid corrosion.

It is clear, whatever the true explanation, that overcleaning can cause blistering, though perhaps it should be mentioned that it does not invariably have this effect. A mildly alkaline solution used anodically or non-electrolytically with short treatment times is, therefore, recommended for cleaning.

The maintenance of correct operating conditions and solution compositions and the provision of adequate facilities for ensuring the absence of impurities from processing solutions are at least as important in plating die castings as in other plating processes.

These principles are familiar to many producers and platers of die-castings who take such steps to ensure a satisfactory product as seems economically justifiable. Despite this, process blistering remains a problem which reaches a serious level at least occasionally. In order to assess the chances of substantially reducing the rejection rate for blistering, it is necessary to know the types of blister occurring and their relative frequency. The first aim of the work undertaken by the B.N.F.M.R.A. is to obtain such information in relation to the production of a small number of plating firms. It has been found that the preparation of a microsection usually enables the cause of blistering to be identified, at least in general terms, and this technique of investigation is therefore being employed. For the routine examination of rejects microsectioning is too laborious, and attempts are therefore being made, incidental to the main investigation, to find some relationship between the cause of blistering and the size, shape, distribution, etc., of the blisters. From the work so far done, it appears that no single cause of blistering is of overwhelming importance and that the more important types of blister may differ from one manufacturer to another. Therefore while it may later be possible to issue general recommendations, at present the best hope of lowering a given manufacturer's rejection rate lies in specific recommendations based on a detailed examination of an adequate sample of his rejects over a period of time. It may be mentioned that so far none of the blisters examined has been found to be attributable to interdiffusion between the copper deposit and the zinc; in fact no diffusion layers have been observed.

Durability of Plated Zinc-alloy Die-castings—Service Blistering

Mode of Failure

Blisters appearing on plated die-castings during service in a corrosive environment are commonly

referred to as "service" blisters to distinguish them from those which occur during processing or shortly afterwards. Service blistering is the most usual mode of failure of plated zinc-alloy articles. Typically, the blisters are open at the top and full of solid corrosion product, implying that they arise whenever penetration of the coating permits attack on the basis metal. In the studies of the durability of plated zinc die-castings summarized by Fenn and Lodder in their paper presented to the first International Pressure Die Casting Conference[11], this mode of failure is assumed and it is supported by other authors[10].

Nevertheless, there is a possible natural tendency on the part of platers to look for other explanations and it is sometimes suggested that blisters may arise in service without penetration of the coating having taken place. This view acquires plausibility from the observation that process blisters occasionally appear some time after processing. But it seems unlikely that blisters arising from trapped electrolyte could take more than a day or two to develop, and they should certainly be in evidence by the time a die-cast component is fitted to a motor car, for example. The possibility of interdiffusion of copper and zinc causing delayed blistering is also small at least for normal conditions of service, as pointed out by Castell[11].

The matter seemed to be one which could be settled finally if more positive evidence were available and the B.N.F.M.R.A. was asked to carry out some tests to this end. To obtain a representative sample of plated die-castings a few were taken each week from the production of two firms until about two hundred castings of many different types had been collected over a period of about six months. These were then exposed on the roof of the Association's laboratories at Euston, after an examination which showed that no blistering had taken place during storage. The castings were subsequently inspected at intervals; as soon as any blistering appeared on the casting it was removed for closer examination. This examination, using a binocular microscope, revealed that the majority of the blisters on any casting were perforated. Even where no perforation was apparent, cutting open the blisters showed that they were full of solid corrosion product—an indication that there must have been a hole in the coating permitting both the ingress of corrosive agents and the escape of gaseous products of corrosion.

It is clear, therefore, that service performance of plated zinc-alloy die-castings is determined primarily by the resistance to penetration of the coating. It is well known that this property depends mainly on the thickness of the coating, assuming it to be of reasonably good quality and free from gross defects. Certain estimates have been made [6, 13, 14, 15] of the coating thickness necessary to ensure acceptable performance and these have presumably been taken into account in drawing up official specifications such as A.S.T.M. B 142 and B.S.1224. The latter requires minima of 0·006 in. nickel and 0·0003 in. copper for the highest quality coating, but it has been questioned whether this is adequate for arduous conditions of service and attention has been drawn to the need for further exposure or service tests. The opportunity is being taken therefore of continuing the exposure of the plated castings referred to above. After a suitable period of exposure, during which the castings are being inspected and assessed at intervals, the coating thicknesses will be measured and the relationship between durability and thickness determined.

Measurement and Control of Coating Thickness

Given a satisfactory specification, it remains difficult to ensure that the specification is met. This is particularly so with die-castings because of their characteristically complex shapes leading to large differences in coating thickness at different points. Current methods of determining thickness are both destructive of the plated article and time-consuming. Recent work at the Association, however, has resulted in the development of a non-destructive method of thickness testing based on the thermoelectric effect. The principle of the method for the measurement of single coatings was described by Heath[16], a similar apparatus was earlier described by Weller and Hanyz[17], but their interpretation of the principles involved is radically different. Although not much work has so far been done on zinc-alloy bases, it is known that it is possible with the B.N.F. Thermoelectric Thickness Gauge to determine rapidly and with reasonable accuracy the thicknesses of both copper and nickel deposits on such bases.

Properties of the Electrodeposits

Thickness is not the only factor influencing the durability of a copper/nickel/chromium coating. Solid impurities in cleaning and plating solutions, swills, etc., can inhibit metal deposition over small areas or give rise to nodules which are torn out of the deposit in polishing. Dissolved impurities in bright nickel solutions particularly may so lower the ductility and increase the internal stress that the coating cracks spontaneously. Gas pitting may occur, arising from a variety of causes. Basis metal irregularities—more common on castings than on wrought materials—may give rise to weak points in the coating. Clearly all such discontinuities will adversely affect the corrosion resistance of plated articles.

It may also be asked whether variations in the nature of the deposits have any effect. Does the substitution of bright nickel for polished dull nickel, for example, lower the ductility? What is the effect of ageing of bright nickel baths, which

are well known to require periodical carbon purification if the quality of the deposit is to be maintained? These are some of the questions which received examination in another of the Association's researches. Much of this work was done in two pilot-scale plating lines, employing proprietary bright nickel solutions and operating under the recommended conditions and at a production rate. Although most of the plating was done on steel the main conclusions would be equally applicable to zinc-alloy and other basis metals. The results of this investigation have not yet been published, but one important conclusion at least may be reported, namely, that bright nickel plating solutions, operated under carefully controlled conditions with proper attention to cleanliness, will consistently and for a reasonably long time yield deposits with a corrosion resistance under normal conditions of service equal to that of polished dull nickel deposits of the same thickness. The conditions of operation are more critical for a bright than for a dull nickel bath, but their maintenance presents no great difficulty if suitable plant is available and use is made of relevant control techniques.

A copper/nickel/chromium coating of appropriate thickness deposited from clean and well-maintained solutions will give good service for long periods. Room for improvement remains, however, since even a thick coating ultimately loses its attractive appearance in a corrosive atmosphere and deterioration may be fairly rapid in severe conditions, especially if the coating is not maintained by periodical wiping and cleaning. Any improvement in corrosion resistance would be welcomed for the further reason that it might permit a reduction in the deposit thicknesses necessary for particular applications with a saving in cost and relief from the worry of recurrent nickel shortages.

In order to decide whether such improvements are possible and by what means they might be achieved, it is necessary to have some idea of the way in which a nickel/chromium coating fails in service. Porosity has for many years been considered to be the controlling factor. The theory is that microscopic pores are present in the nickel coating which permit corrosive liquids to penetrate the coating and attack the basis metal. It is assumed that there exists an intrinsic porosity, quite apart from any gross porosity due to identifiable causes which may or may not be present. The chances of a pore being sealed over increase as the thickness of the deposit increases, so that fewer pores are present in thick than in thin deposits, thus explaining their greater protectiveness. This still seems to be the popular view, but it is doubtful whether there is much truth in it. Many of the so-called porosity tests have been discredited in that they have been shown to have a corrosive effect on the coating as well as on the basis metal. The tests which have little or no effect on the coating rarely show pores to be present in nickel deposits of normal thicknesses applied from clean well-balanced solutions. That thin nickel deposits are permeable to gases has been demonstrated by Thon and his associates[18] (although doubt has now been cast on the validity of some of the results reported [19]), but it has never been shown that such permeability is an important factor in the breakdown of nickel coatings in corrosive atmosphere. The examination of failed nickel/chromium coatings consistently shows that corrosion pitting of the electrodeposited layers precedes attack on the basis metal; in fact many coatings have been examined in which the number of unpenetrated pits in the coating exceeded by a very large factor the number reaching the base. For a fuller consideration of this problem, reference should be made to comments by Thon, Yang and Keleman in parts VII and VIII of the A.E.S. research reports[19] and to a paper by Wesley and Knapp[20] in which the results of extensive weathering tests of nickel/chromium electrodeposits are reported and discussed.

Major improvements in the durability of nickel/chromium coatings are therefore likely to be achieved not by a reduction in porosity, but by an increase in the resistance to pitting corrosion of the deposits. The available evidence indicates that nickel deposits from many types of plating solution now in use vary very little in this respect, but Wesley and Knapp were able on the basis of their work to suggest a number of lines of investigation which might lead to the development of nickel deposits with an improved resistance to pitting. Some progress may already have been made in this direction.

Another approach is possible however. Modifications in the chromium deposit may well have a greater effect than any changes which could be made in the nickel deposit. A flash of chromium on a thin nickel foil reduces the rate at which perforation occurs initially, but greatly accelerates the rate of perforation subsequently[19]. Presumably the chromium itself offers strong resistance to pitting in relation to its thickness; when penetrated, however, the chromium film encourages rapid penetration of the nickel. A thicker chromium deposit would seem to be the answer. It is well known that normal chromium deposits cannot be greatly increased in thickness without cracking. From special solutions or from normal solutions at higher temperatures, thick deposits can be applied, but the processes present difficulties due particularly to the high current densities required; the deposits in any case usually require polishing.

With the aim of developing methods of depositing thick crack-free and bright chromium coatings, a detailed study was undertaken by the

B.N.F.M.R.A. of some of the properties of chromium electrodeposits. A report has already been published by Fry[21] of work on the relationship between internal stress, microstructure and cracking. Subsequent work by the same investigator has led to changes being made in the usual chromic-acid sulphuric-acid electrolyte which permit the deposition at normal temperature and current density of low stress deposits which are free from cracks up to the greatest thicknesses yet attained (0·005 in.). Outdoor exposure and accelerated corrosion tests have shown that deposits 0·0004-in. thick have extremely high corrosion resistance. Unfortunately the deposits are dull and for decorative applications require to be polished. Further systematic and fundamental work is being undertaken in the hope of finding a method of plating such deposits in a bright form. If this is accomplished the effect on the decorative electroplating industry is likely to be profound.

There is a further important consequence of the view that the breakdown in service nickel/chromium coatings proceeds mainly by corrosion pitting. In seeking an accelerated corrosion test for such coatings, there is clearly no longer the need to concentrate on methods which have little or no corrosive effect on the coatings. Indeed appropriate reagents are those which do attack the coatings; the problem is rather to ensure that the attack is similar in character to that occurring in service and yet more rapid. Hence the great interest now being taken in tests employing sulphur dioxide, salt plus acetic acid, and corrosive soils of various kinds.

At the B.N.F.M.R.A. most work has been done on sulphur-dioxide tests. Experiments have shown the fidelity with which service failure can be matched in such tests and recently conducted co-operative trials have shown a highly satisfactory degree of reproducibility between the results of sulphur-dioxide tests carried out in different laboratories. It is hoped to publish an account of this work fairly soon.

Alternative Finishes for Zinc-alloy Die-castings

The development of alternative finishes for zinc and zinc-alloy surfaces is the subject of another of the Association's researches undertaken at the request of zinc industry representatives. One of the author's colleagues has been studying the problem for some two years in an attempt to find methods of producing a finish on zinc having some at least of the properties of anodic films on aluminium. It needs only a little thought to realize that the problem is a difficult one. The obvious approach is to form films on zinc by anodic oxidation, but immediate objections present themselves. Zinc oxide does not normally form thick, dense films well bonded to the metal, as does aluminium oxide, nor does it possess the same capacity for absorbing and mordanting dyes. It is considerably softer than aluminium oxide and, although fairly insoluble in water, it is fairly readily dissolved by dilute acids (as for example in industrial atmospheres). Oxide films produced anodically under appropriate conditions might have rather different properties however, and a number of workers have therefore investigated the possibilities of producing durable films on zinc by anodizing. A summary is given below of these investigations and of others designed to produce films of insoluble or sparingly soluble zinc compounds which might possibly form the bases of protective and attractive finishes.

Fischer and Budiloff[22] examined coatings of oxide produced anodically in sodium-hydroxide solutions. They found that most of them had an adverse effect on the corrosion resistance of the zinc; black coatings produced at higher current densities were rather better in this respect. Voss[23] also anodized zinc in sodium-hydroxide solutions and obtained equally discouraging results. Huber[24] however, reported that the anodic treatment of zinc in sodium-carbonate solutions gave a film with greater electrical resistance which might possibly be more durable. Other work on the physical properties of films produced by anodic oxidation [25, 26, 27, 28] is of interest since it shows the wide variations in properties which can be brought about by varying the anodizing conditions.

Morgan and Lodder[29] produced coatings on zinc by immersion in a cold, saturated solution of oxalic acid. The coating could be dyed in rather dark colours and showed very good wear resistance, but it had virtually no protective action against atmospheric corrosion. Anodic treatment of zinc in 5 per cent. ammonium-oxalate solution gave a whitish coating which was too uneven to test[22].

Chromating processes for zinc yield a film consisting essentially of basic chromium chromate[30]. This is very soft and poorly adherent. It offers good protection in stagnant conditions and even in the salt spray, but it is useless for normal outdoor exposure. It is thought to function by releasing into solution hexavalent chromium which inhibits corrosion if it is not immediately swept away. Anodic[22] and alternating current [31] treatments in chromate or chromic-acid solutions have been tried but there is no evidence that the resulting coating is better than that applied by dipping. The chromate coating is dark (black when produced under a.c. conditions) but can be dyed within a limited range of colour.

Zinc ferrocyanide is a white powder, insoluble in water and dilute acids. An attempt to produce a coating of this salt by anodic treatment of zinc in potassium ferrocyanide gave a colourless, slightly

(*Continued in page* 316)

Finishing of Zinc-alloy Die-castings

(*Continued from page* 315)

iridescent film, which decreased the corrosion resistance of the zinc[22].

Zinc phosphate has not been examined from this point of view, although phosphate coatings are, of course, in common use as a base for paint. Such coatings are, however, normally coarsely crystalline and rather dark; they are not themselves protective, although it is claimed[32] that, following a preliminary dip in a solution of di-sodium phosphate containing a trace of titanium salt, a coating can be obtained which exhibits some corrosion resistance.

It seemed unlikely, on consideration of the above data, that relatively minor changes in the conditions under which the various films on zinc are produced would materially alter the character of the films. Making radical changes in the conditions might result in useful coatings, but it seemed that an equally promising and possible simpler treatment to investigate would be a two-stage process—the formation of the film followed by a treatment designed to modify the properties of the film. In fact, by far the greater part of the work done at the B.N.F.M.R.A. has been on a two-stage process of this kind.

Resulting from this work, patent protection has been sought for a process which has consistently given good results in the laboratory. Since the patent has not yet been published it is not possible here to give details of the process, but a brief description may be given of the properties of the coatings produced by it. The coatings are usually opaque and white on pure zinc, slightly dark on die-casting alloy. The appearance is uniform on rolled samples but sensitive to various surface defects on die-castings, as might be expected. Dyeing is possible with certain dyes. The coatings are hard and abrasion-resistant—abrasion resistances equal to that of normal decorative anodized aluminium have been attained. The finish exhibits considerable corrosion resistance although the coating is attacked by dilute acid solutions.

In the hope that it will lead to further improvement in the quality and appearance of the finish, a fundamental investigation is now being made of the structure and composition of these coatings, using a variety of physical techniques, while further *ad hoc* trials are being made which are concerned with simplifying and improving the process and selecting appropriate dyes.

Acknowledgments

The author is indebted to the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish this account of our work, and thanks his colleagues, particularly Mr. H. Fry and Mr. M. A. Haughton, for their assistance in preparing this paper.

References

(1) Petrocelli, J. V. and Phillips, A. *Trans. Electrochem. Soc.* 1944, **85**, p. 257.
(2) Stephenson, W. G., *Product Finishing*, 1956, **20** (4), p. 28.
(3) Wallbanks, A. W., *J. Electrodepositors' Tech. Soc.* 1939, **15**, p. 87.
(4) Caldwell, M. R., *Plating*, 1948, **35** (2), p. 135.
(5) Maher, M. F., *Proc. Amer. Electroplaters' Soc.*, 1941, p. 128.
(6) Anderson, E. A., and Reinhard, C. E., *Plating*, 1948, **35** (2), p. 145.
(7) Oplinger, F. F., *Proc. Amer. Electroplaters' Soc.*, 1940, p. 70.
(8) Lewis, B. F., *Proc. Amer. Electroplaters' Soc.*, 1940, p. 64.
(9) Roberts, C. W., *Metallurgia*, 1954, **50**, p. 207.
(10) Wernick, S., Symonds, H. H. and Castell, H. C., *J. Electrodepositors' Tech. Soc.*, 1949, **24**, p. 195.
(11) Fenn, A. P., and Lodder, L. A. J., *Zinc Alloy Die Casters' Association*, International Pressure Die Casting Conference, October 15th-28th, 1954.
(12) Castell, W. F., *Trans. Electrochem. Soc.*, 1934, **66**, p. 427.
(13) Nixon, C. F., *Monthly Rev. Am. Electroplaters' Soc.*, 1945, **32** (11), p. 1104.
(14) Caldwell, M. R., Sperry, L. B., Morse, L. M., and Delong, H. K., *Plating*, 1952, **39** (2), p. 142.
(15) Metals Handbook Supplement, A.S.M., 1955, 97.
(16) Heath, A. R., *Metal Finishing Journal*, 1955, **1** (4) p. 145.
(17) Weller, E. F., and Hanyz, E. A., *Iron Age*, 1954, **173** (9), p. 162.
(18) *See* reports on A.E.S. Research Project No. 6 "Porosity of Electrodeposited Metals":—
(I) Thon, N., and Addison, E. T., *Monthly Rev. Amer. Electroplaters' Soc.*, 1947, **34** (4), p. 445.
(II) *ibid*, **34** (5, 6, 7), pp. 568, 722, 831.
(III) Thon, N., and Keleman, D., *Plating*, 1948, **35** (9), p. 917.
(IV) Thon, N., Keleman, D., and Yang, L., *Plating*, 1949, **36** (4), p. 362.
(V) *ibid*. 36 (9), p. 928.
(VI) *ibid*, 1950, **37** (3), p. 280.
(VII) *ibid*, **37** (6), p. 631.
(VIII) *ibid*, **37** (7), p. 749.
(IX) *ibid*, **37** (7), p. 752.
(X) *ibid*, 1951, **38** (10), p. 1055.
(XI) Thon, N., Yang, L., and Yang, S., *Plating*, 1953, **40** (9), p. 1011.
(XII) *ibid*, **40** (10), p. 1135.
(XIII) Thon, N., and Dean, D., *Plating*, 1954, **41** (5), p. 503. *See* also Ewing, D. T., Tobin, J. M., and Foulke, D. G., *J. Electrochem. Soc.*, 1956, **103** (10), p. 545; *ibid*, **103** (12), p. 648. Foulke, D. G., and Tobin J. M., *Proc. Amer. Electroplaters' Soc.* 1956, p. 234.
(19) Ogburn, F., and Benderly, A., *Plating*, 1954, **41** (1), p. 61; *ibid*, 1954, **41** (2), p. 169.
(20) Wesley, W. A., and Knapp, B. B., *Trans. Inst. Met. Finishing*, 1954, **31**, p. 267.
(21) Fry, H., *Trans. Inst. Met. Finishing*, 1955, **32**, p. 107.
(22) Fischer, H., and Budiloff, N., *Metal Industry*, 1940, **57**, p. 222.
(23) Voss, K., *Z. Metall u. Schmuckwarenfabrik, sowie Verchromi*; 1941, **22**, p. 270; *Chem. Zentr.* 1941, **112**, p. 2376.
(24) Huber, K., *J. Electrochem. Soc.*, 1953, **100**, p. 376.
(25) Müller, E., and Schwabe, K., *Z. Elektrochem.*, 1932, **38**, p. 407.
(26) Huber, K., *Z. Elektrochem.*, 1942, **48**, p. 26.
(27) Huber, K., *Helv. Chim. Acta*, 1943, **26**, p. 1037; *ibid*, 1943, **26**, p. 1253; *ibid*, 1944, **27**, p. 1443.
(28) Huber, K., and Bieri, B., *Helv. Phys. Acta*, 1948, **21**, p. 375.
(29) Morgan, S. W. K., and Lodder, L. A. J., *J. Electrodepositors' Tech. Soc.*, 1936, **11**, p. 87.
(30) Anderson, E. A., *Proc. Amer. Electroplaters' Soc.*, 1943, p. 6.
(31) Schulein, J., *Trans. Electrochem. Soc.*, 1943, **66**, p. 223.
(32) Jernstedt, G., *Trans. Electrochem. Soc.*, 1944, **83**, p. 361.

Production and Applications of ALUMINIUM POWDERS AND PASTES

An Account of Practice at the Louisville, Kentucky, works of REYNOLDS METALS CO.

(*Continued from page* 298 *July*, 1957)

Applications

BY FAR the largest and most important use of aluminium powders and pastes is as pigment for coatings of all types. When mixed with proper vehicles, aluminium pigments produce finishes that are unusually effective in affording long life to the material they cover. This exceptional protection is due to the high reflectance of aluminium pigment, its great resistance to penetration of moisture, remarkable durability and low emissivity.

Aluminium Paints and Coatings

The unique characteristics of aluminium pigments are responsible for the remarkable protection afforded by aluminium paints, their permanently bright appearance and great resistance to deterioration.

Mechanical Reinforcement

The aluminium flakes within the dry film act as reinforcing pigment to mechanically strengthen the film and so give added protection against failure.

Leafing

The minute metal flakes used in most aluminium paints are polished and coated with a special agent during manufacture to give a surface not easily "wetted" by usual paint vehicles. This produces a high interfacial tension between the flake and the liquid vehicle. As a result, the flakes, although heavier than the liquid, tend to float to the surface and to lie parallel with it, overlapping each other on the surface and within the paint film. The arrangement resulting, very similar to that of fallen leaves on the ground, is called "leafing".

Such a paint film consists of numerous layers of aluminium flakes with layers of vehicle between them. These vehicle layers protect the film against the effects of heat and cold (expansion and contraction), providing increased resistance to cracking, distortion and flaking off. The flakes floating to the surface result in the vehicle having little effect on the appearance of the coating since only an extremely minute layer of vehicle lies between the top of the coating and the first layer of flakes. For the same reason, the degree of leafing has a great influence on appearance as well as other characteristics of the coating.

Opacity

Being actual metal particles, the aluminium flakes themselves are opaque and so do not transmit light or other forms of radiant energy, including the damaging ultra-violet rays from the sun. Thus the overlapping flakes in the upper layers of an aluminium paint coating stop these rays and thereby protect the underlying layers of vehicle. This self protection from deterioration inherent in all aluminium paints is the factor accounting for their unusual long life.

Hiding Power

In any series of paint coats the first is the most important in hiding the colour of the surface being covered. For this reason it is desirable for the first coat to have maximum hiding power to reduce the total number of coats required.

A well-formulated aluminium paint, being made up of overlapping opaque metal flakes, is itself opaque and so will usually hide the underlying surface completely in a single coat. Since this same coat also has high reflecting power, combined with a light, attractive appearance, the one coat is often sufficient for interior walls and ceilings where good lighting efficiency is required.

Moisture Resistance

A paint film like that described above has a number of highly valuable features. Possibly most important is its remarkable resistance to the penetration of moisture. It is evident that moisture cannot penetrate through the individual flakes themselves, since they are metallic aluminium, without pores. Although extremely thin, the aluminium in these flakes will not permit the passage of liquids or even gases.

As moisture cannot pass through the individual flakes, the only way it can penetrate the paint film is to enter between and around many overl pping flakes. Since the shortest dimension (length or width) of a flake is usually several hundred times

its thickness, it becomes evident that moisture must travel just that much longer a path to get through the paint film. The net result is that the film offers the same resistance to the penetration of moisture as would be expected from an ordinary paint film many times as thick.

Weathering

This resistance to penetration is extremely important, for it means that aluminium paints provide excellent sealing qualities. Usually one coat can be depended upon to seal almost any surface. This assures protection to the surface underneath, regardless of what it may be. Iron and steel parts resist rust if their surfaces are clean and sealed against moisture. Brick and masonry life can be extended greatly when moisture is excluded from entering, because most deterioration of such materials is due to entrance of moisture, and subsequent expansion upon freezing with resulting cracking and weathering at the surface.

Surface cracks rapidly propagate deeper where no protection against entrance of moisture is provided. This sealing of the surface is of utmost importance in extending the life of wood structures. By preventing the entrance of moisture into the wood through the painted surface, it reduces the disintegration that results from the shrinking and swelling of wood with changes in moisture content. The barrier provided by aluminium paints is doubly valuable in that it not only prevents entrance of moisture from the outside but it also reduces the rate at which moisture can escape from the material it covers. Thus it greatly reduces any change in moisture content of wood, thereby preventing weathering and so extending the life.

For the same reason a single coat of aluminium primer is exceptionally valuable in coastal areas or other locations of high humidity in that it cuts excessive absorption of moisture to a point where the tendency of paint to peel and blister is greatly reduced.

"Bleeding" of Undercoats

The ability of aluminium paints to seal outwardly as well as inwardly is often valuable in covering coloured oil-soluble undercoats such as oil stains, bituminous paints and the like. Covering these paints with ordinary white or other light-coloured paints is almost certain to result in enough of the undercoat being absorbed into the top coat to show through, with unattractive stains appearing on the top surface.

Aluminium paints are helpful in such cases, if properly formulated and properly applied, as they provide a good seal between such undercoats and a white top coat. One coat of correctly formulated aluminium sealer is usually sufficient, and a coat of aluminium paint itself may be sufficient without an added top coat, since its bright, light colour is suitable for many applications of this nature. For example, it is sufficient to increase the visibility of creosoted poles and posts used on highways; and to produce a bright attractive surface on cork-board or other insulating building materials that are coated with mastic or bituminous waterproofing material.

The vehicle used with the aluminium pigment must be of the proper type. It is also important to avoid disturbing the undercoat. For this reason, spraying is often preferred to brush application.

Reflectivity

Since the painted surface consists of a layer of pure aluminium particles, the paint approaches the high reflecting power of aluminium itself. Furthermore, as aluminium reflects up to 75 per cent. of the radiant energy striking it, this feature imparts a high degree of protection to the paint film itself.

The outer layers of aluminium particles protect the underlying layers of vehicle against "weathering"—a form of deterioration partially due to radiant energy from the sun with its highly destructive rays. Ordinary light is also reflected efficiently, making aluminium paints highly visible and affording an exceptionally attractive, soft, silvery finish.

Lowers Temperatures

The ability of aluminium painted surfaces to reflect heat is of utmost importance in reducing evaporation losses of tank cars, storage tanks and outdoor processing equipment. Sheet steel magazines used to house explosives are covered with aluminium paint to advantage. For example, one test compared temperatures inside two identical structures, one of which was painted with aluminium. As much as 14° F. lower temperatures were reported for the aluminium-covered unit with its temperature never exceeding outside shade temperatures.

Another test that reveals the reflecting efficiency of aluminium was made on a built-up asphalt roof. A thermometer was inserted between the first and second layers of felt where it registered 150° F. when it was 95° F. in the shade. Only 15 minutes after applying an aluminium roof coating the same thermometer registered 112° F.—an actual temperature reduction of 38° F.

Low Emissivity

A property almost the opposite of reflectivity is emissivity or heat radiating power. Thus the high reflectivity of aluminium paint is accompanied by a corresponding low emissivity—about 30 per cent. for aluminium painted surfaces at 100° F. The emissivity of a theoretically perfect radiator is taken to be 100 per cent.) The low emissivity of aluminium paints affords a number of important advantages, chief of which is the ability to conserve heat in objects so coated. This means that a given

furnace temperature can be obtained with less heat input, or that a higher maximum furnace temperature can be reached with a given heat input.

The reduction of heat radiated from hot sources by coating them with aluminium paint greatly increases the comfort of workers in the vicinity of heat-treating furnaces, chemical equipment, etc. Although reduced radiation results in higher surface temperatures, the low emissivity of the aluminium "dams up" the heat at the surface. These higher surface temperatures permit more heat to be dissipated by convection currents in such items as steam heating radiators. This is a desirable condition since it provides a reduction in heat radiated to walls, ceilings and floors—heat often regarded as wasted—while adding to the comfort of the occupants of the room by increasing the amount of heated air from convection currents.

Oxidation Resistance

A transparent oxide coating forms on aluminium instantaneously due to the great affinity of aluminium for oxygen. This complete and rapid natural oxidation of aluminium is important in aluminium paints because it provides assurance that the aluminium particles have already been oxidized and so are unaffected by further exposure to the air.

This inertness of aluminium paint particles affords in turn an unusual degree of protection to the metal surfaces they cover. Thus stacks, flues, vents, piping and other items subject to rapid deterioration from the combined action of heat and exposure to the weather are provided with an important means of extending their life.

Non-leafing Pigments

There are certain finishes in which the leafing characteristic of aluminium pigment is not desired, because it has been found that if non-leafing, the pigments will not rise to the surface but will remain in the body of the paint film as it sets. The result is that the random oriented flakes catch the light at different angles to produce a satiny or silky effect. The appearance of depth is achieved by the fact that each different angle at which the object is viewed with the eye brings into play light reflections from a new combination of flakes. By adjusting the distribution of coarse and fine flakes, the effect can be greatly enhanced.

Polychromatic Finishes

Coatings so called combine a "mother-of-pearl" effect with coloured pigments which breaks up the light into different shades as the angle of view is changed. "Pearlessence", a product obtained from fish scales, was first employed to produce finishes of this type, but its high cost and non-uniformity made it necessary to find a more economical and reliable pigment. Mica was also tried but not with complete satisfaction due to wide variations in colour and structure.

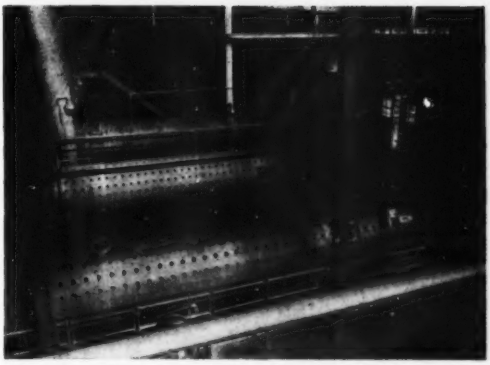


Fig. 11.—Three large ball mills for grinding granular aluminium powder into fine flake-type paste, suitable for paint pigment.

It was found that leafing-type aluminium pigments could be made non-leafing by special patented processes. These impart the "colour change" effect so desired in polychromatic finishes.

Many popular finishes of this type utilize tones of grey, blue, red, green, etc., giving the appearance of a metallic base of polished aluminium over which has been applied a transparent coloured coating.

Metallic, hammered, crackle and wrinkle finishes are also prepared using these non-leafing aluminium pigments. Generally, coarser grades are more suitable for applications where considerable sparkle in the finish is desired.

Paint Application

Aluminium paint, as received for field application is available in two forms. Ready mixed, or to be mixed just before application.

In ready-mixed form the correct amount of aluminium pigment has been combined with the vehicle at the factory. Specially-designed vehicles are used for this form of aluminium paint so that leafing and brilliance are retained—ordinary vehicles (and especially those containing lead driers) are not suitable for ready-mixed aluminium paint. Some slight settling of aluminium pigment may have occurred in storage and the ready-mixed aluminium paint should be stirred (using an additional container if necessary) until the pigment is distributed uniformly in the vehicle.

In paint that has to be mixed before application the vehicle and the aluminium pigment are received in separate containers—either in double compartment cans or in entirely separate packages.

Thoroughly mixing the pigment, in either powder or paste form, with the vehicle is a most important step. The pigment required should be carefully measured for the amount of vehicle to be

used. Some of the vehicle is then added to the pigment—a little at a time—with thorough stirring until a heavy uniform consistency is obtained at which time the balance of the vehicle may be added and the whole stirred until uniform.

Any type of aluminium paint should be kept sealed until used, or resealed if use is interrupted. In addition, aluminium paint should not be stored where it is exposed to high temperatures and if opened should be protected against the admission of water or moisture in any form.

Most aluminium paints are shipped in either form —so that the mixed vehicle and pigment will be of correct consistency. If any thinning is required this should be done strictly in accord with manufacturers' instructions.

Surface Preparation

All surfaces to receive aluminium paint should be clean, dry, and free of loose particles. Where special primer is required and applied this primer coat should present a completely dry and not too glossy surface.

Brushing

For brush application the brushes used should be clean and of the best type and quality possible to obtain. Painting should be done with a fairly wet brush and wherever possible to a wet edge with all finishing strokes in the same direction. Overbrushing should be avoided. When the paint has been applied, leafing should start at once and be completed long before initial set is reached. Any attempt to retouch or go over aluminium paint which has just been applied will result in blemishes caused by alteration of the leafing structures.

Care should be taken—especially when working on large metal structures such as bridges or oil storage tanks—to ensure that no moisture or dew is present on the surface. During some periods of the year moisture may be present when work is started in the early morning and must be removed before painting. Usually those areas in the sun will be first to dry, so many paint "with the sun" as the rays fall progressively around the tank or structure.

Cold surfaces (below 45° F.) chill and thicken the paint so that proper spreading and leafing is not obtained; heated surfaces (above 120° F.) may cause similar trouble because of the too rapid evaporation of the volatile solvent (except those high heat paints especially designed for application on warm or hot surfaces).

When finishing articles or surfaces by brush where extremely smooth effects are desired the paint should be strained after mixing, and the usual precautions taken to ensure application and drying in a dust-free area.

Dipping

Vehicles for dipping should be designed for the particular type of coating desired. Their general characteristics should include rather rapid "setting", non-wrinkling or silking in the baking cycle used, complete drying after the full baking cycle so that finished articles may be immediately stacked or handled without danger of sticking, and the ability to hold aluminium in suspension in the dipping tank without discolouration or the forming of skins. Top drying is more or less essential and usually cobalt naphthenate solutions are used.

If material is to be mixed with pigment and allowed to remain in the tank for long periods of time, the use of lead driers may cause loss of brilliance of the pigment. Iron driers may be used to eliminate tendencies toward wrinkling or silking on baking.

The rate of withdrawal of the article from the dipping tank is an important factor in securing a good coating and a uniform withdrawal rate is essential. A heavy bead forming on the lower edge of the article dipped and baked generally indicates too heavy a "body" in the mixed coating in the tank. Agitation of the mixed coating in the tank, especially when held for any length of time, is helpful in securing uniform coatings. This may be done by hand or by mechanical mixer; agitation by means of compressed air has not proved to be entirely satisfactory.

A resumé of the requirements as outlined indicates the use of vehicle formulations with low viscosity and thinners with fairly fast evaporating rates and high solubilities. The desired characteristics of flexibility, baking requirement, resistance to moisture or other corroding influences will vary in different plants, and formulations will be further varied by costs allowed for baking vehicles. These same general characteristics will be required for spray finishes requiring baking.

Aluminium pigments for these coatings are required to give good colour (whiteness) and brilliance. Finished coatings are generally demanded that give a metal "plated" finish (the so-called "chrome" finish). Extra fine pigments with high coverage value are generally required.

There is some indication that in withdrawing the object from the coating tank, that a higher ratio of aluminium to coating solids is present on the object than in the tank. While this has not been definitely proved, it is advisable to check the ratio of aluminium solids to coated solids at frequent intervals and also to check on the proportion of volatile matter and non-volatile matter in the tank where some evaporation of the volatiles may occur. At these times additions of more thinner or aluminium pigment may be made.

Flow Coating

This process is in some ways similar to dipping from the standpoint of vehicle requirements. In this method the mixed coating is poured or flowed over the material to be finished. The apparatus

used is simple, requiring a relatively small holding tank for the mixed coating and a pump or series of pumps to lift the material from the tank and allow it to pour over the piece to be coated, the excess draining back to the tank.

A slightly heavier viscosity as compared to the viscosity of coatings applied by the dip method is usual. Fairly fast evaporating solvents should be used and if a leafing finish is desired, the vehicle should be very stable to leaf retention because of the excess agitation supplied by the pumping system.

The characteristics of vehicles follow those as covered under "Dipping". The advantage of the flow coat method is that a smaller tank and thus less mixed material is required at one time.

Spray Coating

The use of spray equipment gives a quick, uniform, economical method of applying aluminium coatings to most work. No special spray equipment is necessary to handle aluminium coatings as their characteristics make them suitable for this method. In the field only rough screening of the material is required to take out any undispersed particles. But in spraying finishes such as are applied on car bodies, metal office equipment, etc., the screening operation is a very important step in ensuring a smooth and pleasing appearance. Relatively low pressure should be used, and if mechanical or air agitation in the paint pot is not provided, the contents should be stirred and re-mixed occasionally while in use.

The condition of the tank hose and gun are as important in obtaining good finishes as is the material used. Even small particles of coating allowed to dry or set in the material line or in the gun head may cause complete stoppage or a spattering effect. One of the great dangers in air spray application is the tendency to obtain too great a coverage, resulting in a finished coating too thin for practical work and an unsatisfactory appearance of the finished work. The skill of the operator is an important part of the application process, particularly in such novelty finishes as those giving hammered or crackled effects upon drying.

Usually it is necessary to have the material tank fairly close to the point of application, but apparatus has been designed especially for roof application on large areas where 55-gallon drums of the mixed coating can be kept at street level and pumped through a material line to the point of application. In the finishing of structural steel tanks, etc., dust settling on the work is not controllable, but in the finishing of such objects such as metal novelties, etc., an approved type of spray booth providing for the withdrawal of paint mist should be provided, and careful control of the spray-room conditions be enforced to assure the minimum of dust or suspended particles which might settle on the finished work before drying.

Aluminium is not toxic, but the fumes from coal-tar solvents, petroleum solvents and lacquer diluents are extremely toxic to some people and for this reason approved types of respirators should be worn by the spray operators. It is usual to obtain aluminium coatings in a heavier viscosity than is required for spraying and to dilute them to correct spraying consistency by the use of additional solvent. The selection of the solvent should take into full consideration its compatibility with, and its solubility for, the particular coating required.

Lacquers, because of their quick drying characteristics, are usually applied by air-spray apparatus, as are some of the new, fast-drying synthetic types of vehicles. In formulating coatings for spray application it should be kept in mind that regardless of the amount of thinner used, a definite ratio of aluminium pigment solids to vehicle solids should be maintained. Equipment, including all hose lines, should be thoroughly cleaned when work is interrupted or ended for the day to maintain high spraying efficiency.

Because of the possibility of inflammable fumes being present, all electrical equipment such as lights, motors, etc., in the spraying area should be of the non-sparking safety type. The booths themselves, especially when spraying lacquer, should be cleaned often to remove any of the coating material which might lodge therein in the form of flakes or dust particles.

Paint Formulae

Pigments

Both paste and dry powder are used as paint pigments, the greater ease of handling in paste form making that form preferred for the more finely divided particles. Pastes usually contain 65 to 75 per cent. pigment, the remainder being a volatile paint thinner or liquid compatible with the paint vehicle to be used.

Most aluminium paints contain about 1½ lb. of aluminium pigment per gallon of paint and may range from ¾ to 3 lb. per gallon. This contrasts with lead paints which may contain up to 30 lb. of pigment per gallon. A typical varnish vehicle for aluminium paint should weigh over 7 lb. per gallon.

Vehicles

It is possible to divide aluminium paint vehicles into two general classifications—oil base, resin base or oil-resin base vehicles, commonly known as varnishes, and vehicles employing materials such as cellulose as the film-forming base, commonly called lacquers.

Varnishes are the most widely used vehicles for aluminium pigments. These oleo-resinous vehicles

usually contain a drying oil, a resin, a drier and a volatile solvent for the resin. The drying oil may be tung oil (Chinawood oil), linseed oil, fish oil, dehydrated castor oil, or any other of a wide variety, or a mixture of these oils.

Resins are of many types, including phenolic condensation resins; ester gums; paracoumarone resins and others made by polymerization; the alkyd resins and others made by reacting polyhydric alcohols and polybasic acids or anhydrides. Resins are also made from crepe rubber, chlorinated rubber and many other materials.

The ability to aid leafing is often essential for varnishes to be used with aluminium pigments. Aluminium paints made with usual varnish vehicles intended for air drying may show a slight tendency for the pigment to rub off after drying. This is caused by the leafing action being so strong as to make some of the metal flakes actually rise above the surface of the binding media. This difficulty can be reduced by using less pigment, by adding a portion of non-leafing pigment, or by increasing the proportion of oil to resin. It can be eliminated entirely by using a non-leafing pigment exclusively.

Oil Length

A term that refers to the proportion of oil to resin in varnishes is "oil length"—the number of gallons of oil per 100 lb. of resin. Thus a 35-gallon oil-length varnish is formulated with 35 gallons of oil per 100 lb. of resin.

Little or no oil is used in certain vehicles such as those for high-temperature paints where the vehicle consists chiefly of a resin dissolved in a suitable solvent. On the other hand, requirements for such uses as wood primer where unusual toughness, flexibility and moisture resistance are wanted, may dictate the use of a low resin ratio (long oil length), the vehicle consisting almost entirely of treated oils with driers and a small amount of volatile thinners.

For priming raw lumber before coating with usual outdoor house paints, very long oil varnishes, with Kauri reduction values above 100 and preferable near 150, should be used. In addition to oil and resin, all varnishes contain volatile thinner to reduce the viscosity, and a drier is added to produce the desired drying characteristics.

Viscosity control is always essential because the thinner the vehicle, the more easily can the individual flakes of aluminium move about in it to form the layers which characterize the leafing aluminium pigments; a thick vehicle will hinder leafing. Usually viscosities ranging from A to C on the Gardner-Holdt viscosity tubes or 25 to 30 seconds on a No. 4 Ford Cup provide best results. The specific gravity of the vehicle and other factors also influence the leafing action. When powders are used vehicles of thinner viscosity should also be used than with pastes.

Vehicles for Lacquers

For production finishes such as in the car and furniture industries where quick drying is essential and where excellent durability must be combined with attractive appearance, modern high-solids-content cellulose-base finishes occupy an outstanding position. They usually are formulated with nitrocellulose, ethylcellulose, cellulose acetate esters and other materials. These are generally dissolved in high-solubility volatile liquids or thinners. Volatile mixtures are added beneficially to modify the fluidity, rate of drying, and the like.

Various materials called plasticizers are added to increase the toughness of the lacquer film. Certain gums and resins are also included principally to provide hardness.

Another form of lacquer application becoming increasingly popular is known as a "hot lacquer system". Aluminium pigments are used in this type of coating as well as those mentioned above for aluminium and polychromatic finishes. The hot lacquer system is very much the same as conventional lacquer systems except the solids are higher and it is sprayed on hot thus reducing the amount of volatile solvents used with a resultant thicker one-coat film.

Coatings made with alkyds, melamines, ureas, or other synthetic resins are used to produce hard, dry finishes that exhibit excellent resistance to attack by high temperatures, various chemicals and solvents. Application of aluminium coatings made with these vehicles is usually by means of a spray gun, with drying at elevated temperatures.

Bituminous Vehicles

Noted for their moisture resistance and waterproofing power, these vehicles are essentially "cut-backs" of petroleum-base asphalts, asphaltites, or coal tar, with or without the addition of driers or oils. Included in this class are the petroleum-base resins.

Because of the need for complete covering of the dark vehicle, high leafing power is required of the aluminium pigments for use with these vehicles. The vehicle should have as low a viscosity as possible and as high a specific gravity as possible to aid leafing.

In application of these coatings, overbrushing must be carefully avoided or dark streaks will be produced by disturbing the partially set surfaces.

Bituminous-base aluminium roof coatings differ from bituminous-base aluminium paints as they are usually so formulated as not to dry to a hard film. In some instances asbestos or other fibrous material is incorporated.

(To be concluded)

A Survey of AIR TREATMENT SYSTEMS in use in the Metal-Finishing Industries

by LEO WALTER, A.M.I.H.V.E., A.M.I.Plant.E.

(*Continued from page* 202, *May*, 1957)

INDUSTRIAL dust removed from processes where solid particles vitiate the air, such as grinding, or where during processing dust and dirt is created requires a dust removal system. The Factories Act, 1937, implies that precautions must be taken "to protect the persons employed, against inhalation of the dust, or fumes or other impurity and to prevent its accumulation in any workroom". And furthermore the Act demands that "in particular where the nature of the process makes it practicable, exhaust appliances shall be provided and maintained, as near as possible to the point of origin of the dust or fume or other impurity, so as to prevent it entering air of any workroom". (Fig. 1.)

The law intends to protect workers' health in the first instance, but obviously has had to leave detailed interpretation to local circumstances. Metal treatment in general is very diversified, and each process whereby dust is created requires a different approach for dust removal. For example, mechanical cleaning operations embrace among others grinding, brushing, wire brushing, and

Fig. 1 (*left*).—*Sheathed-wire element plant for paint stoving on components transported by wire-mesh belt conveyor. Fume-removal system with hood.*

(*Courtesy of the General Electric Co. Ltd.*)

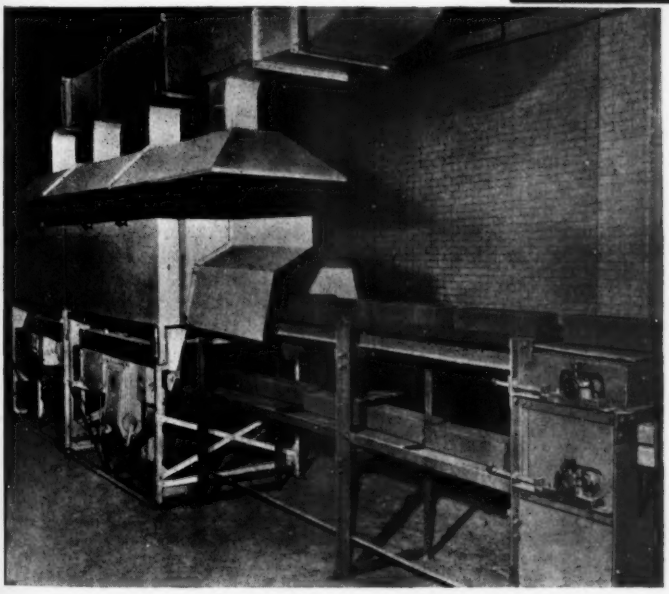


Fig. 2 (*above*).—*Single portable dust-extraction unit.*

(*Courtesy of A. E. Griffiths (Smethwick) Ltd.*)

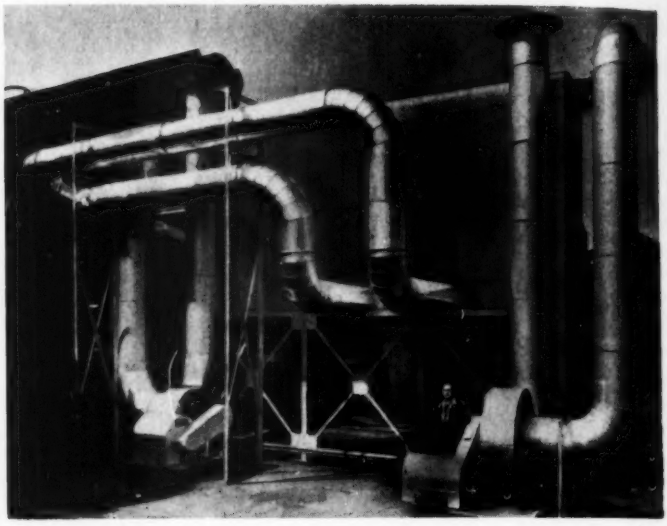


Fig. 3 (right).—Filter bank and fans in dust-extraction system. (Courtesy of A. E. Griffiths (Smethwick) Ltd.

blasting of metal surfaces. Wheel grinding, or band or belt grinding requires hoods or enclosures for each machine, connected by ductwork to the exhaust fan and collector. Self-contained units are also available for large machines (Fig. 2).

The use of quartz sand as a blasting medium is now only permitted in this country by special dispensation because of the danger of silicosis, and it has been almost entirely replaced by chilled iron or steel shot and grit. In certain specialized applications alumina, zircon sand, or other synthetic abrasives are used.

For the treatment of smaller components a range of shot-blast cabinets is available in which processing is carried out in isolation from the workshop atmosphere. Dust is extracted directly from the cabinet and the operator watches the progress of the work through a viewing window and directs it by means of box gloves.

A variation of this process is sludge or vapour blasting in which the abrasive is mixed with a liquid, usually water, and is directed at the component from a jet through which it is forced by steam or compressed air at a pressure of around 80 lb. per sq. in.

Mechanical polishing and buffing using fabric mops rotating at high speed, is a notoriously dirty process, and in order to remove the dust and particles arising from such polishing operations it is usual to install hoods as close to and covering as much as possible of the wheels as is compatible with efficient operation.

The success of any installation for dust removal depends on design of hoods, ducting and of extraction fans. The compromise sought for location of hoods is, that they must not interfere with the plant operation, but must catch as many particles as possible. The efficiency of a dust system depend on careful calculation of diameter, bends, T-pieces, etc., and correct estimation of flow resistance is vital. Branch connexions must be designed to join up with the main duct at correct angles (Fig. 2). Obviously the power consumption of the fan motor is an important item of running costs, and a minimum of resistance to air flow is required from an efficient duct system. Another point is cleanliness of ducting. Large cleaning openings with tight doors should be provided for. The construction of bends, tapers, and straight line ducting must ensure that dust cannot lodge in the system. It is not often possible to remove dust and refuse and discharge direct into the atmosphere. Separators, cyclones or filter banks are used (Fig. 3). Bag filters, centrifugal separators, wet-type dust quenchers, dry settling chambers, etc., have to be installed according to local conditions. (Electrostatic dust collection will be dealt with in a later instalment in connexion with air filtering.) In order to minimize abrasion in fans, ductwork and cyclones special lining is sometimes applied. For example at a works in which the cowling has worn out in six months rubber lining has been applied to save friction in the metal ducts, etc.

It should be noted that there are specific requirements by law for the provision of exhaust draught for the removal of dust and fumes in a number of industries. These are contained in Regulations which are set out in Factory Orders. Such concern the following processes: Brass casting, bronzing, chromium plating,* vitreous enamelling, grinding

* It is noteworthy that the regulations concerning the exhausting of chromium-plating equipment have been modified to permit as an alternative the use of a proprietary surface active agent whereby the evolution of chromic-acid spray from the bath is inhibited.

of cutlery, miscellaneous grinding, vehicle painting, use of paints and colours, tinning, and others.

Factors in Exhaust System Design. (Fig. 4.) There are two general arrangements for industrial exhaust systems, namely the central system and the group or unit layout. In a central system a single or double fan is located near the centre of the shop with a piping system leading to the various machines. In the group system small individual exhaust fans are located at the centre of machine groups if the latter are scattered, or complete units are attached to each large machine. Dust or refuse may be collected by enclosing hoods, by open hoods, or by means of exhaust fans in walls, windows, etc., ventilating the whole room. Plating plants, pickling tanks and the like may employ open hoods. An open hood should be placed as close to the source of dust or fumes as possible, with due regard to the necessary operator movements. Because of rapid diffusion, hoods placed at some distance should be large enough to catch the rising fumes and air. In another class of operation the main objective is to prevent escape from dust into the surrounding atmosphere. In these instances the removal of some dust is merely incidental. Some dust and fume producing operations are best carried out by isolating the process in a separate compartment or room. General ventilation may or may not be sufficient if workers have to stay in such enclosures. Any ventilating system employed should be designed so that a strong clean air current is drawn across the operator, and directed then away from him toward the work. Exhaust fans carry the dusty air away.

No general rules can be given for design of a dust removal system, but the potential user should specify the following: (1) Adequate size of hoods, ducts, fans and collectors; (2) Sufficiently high air velocities; (3) Minimum power consumption; (4) Easy access for inspection and maintenance at all points of the system; (5) All rules and regulations set up by authorities must be fully obeyed.

Accessibility of guarded parts of machines is, of course, important. For example, hoods for grinding, polishing and buffing should fit closely, but give easy access for changing wheels. A removable cover at the base of a hood is advisable to capture heavy dust particles and things dropped by the operator. Large open hoods for electroplating and pickling tanks should be sub-divided. Often the main exhaust duct is branched for obtaining a uniform flow (Fig. 5). Canopy hoods take advantage of the natural tendency of warm vapoure or air to rise. A widely used exhaust method for chromium plating and other process tanks makes use of drawing air and fumes laterally across ths

(*Continued in page* 338)

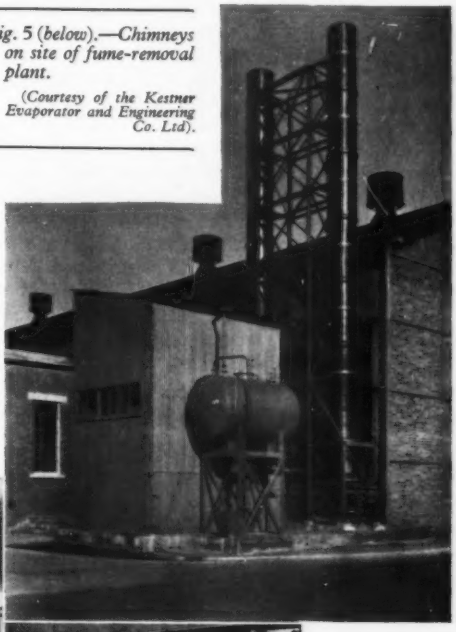


Fig. 5 (*below*).—*Chimneys on site of fume-removal plant.*

(*Courtesy of the Kestner Evaporator and Engineering Co. Ltd.*).

Fig. 4 (*right*).—*Exhaust plant installed on fume-removal system for metal-finishing vats.*

(*Courtesy of the Kestner Evaporator and Engineering Co. Ltd.*)

THE EFFECT OF CERAMIC COATINGS ON CREEP

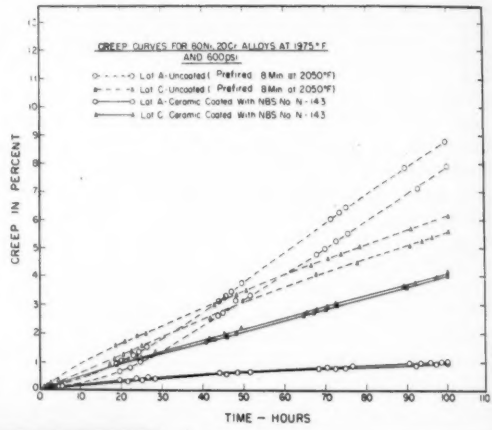
Report of an Investigation made by the U.S. Bureau of Standards

REFRACTORY-TYPE ceramic coatings have come into widespread use on metal parts exposed to high temperatures, as in aircraft engines, and the U.S. National Bureau of Standards recently undertook a study of the creep behaviour of coated specimens under different temperature-stress conditions. Ceramic coating N-143, which contains cerium oxide for refractoriness, was applied to specimens machined from thin sheet metal. The alloys studied included two 80/20 Ni/Cr alloys ("A" and "C") differing significantly in manganese, iron, and silicon content, alloy "A" containing the higher amount of these constitutents.

The tests at 1975° F and 600 and 1200 lb. per sq. in. showed the greatest reduction in creep rates of the ceramic-coated specimens. Under these conditions the beneficial effect of the coating on the creep behaviour of both 80/20 Ni/Cr alloys is sufficient to be of practical importance. At 1975° F and 600 lb. per sq. in. the creep rate of uncoated "A" specimens is higher than that of "C". However, the reduction in creep rate imparted by the coating is so much greater with "A" alloy that the creep rate of the coated "A" specimens is significantly lower than that of the coated "C" specimens.

Internal void formation was observed in the uncoated specimens tested at 1975° F and at 1900° F, and the uncoated specimens lost twice as much chromium as the coated specimens tested at the same temperature. Little void formation was observed in the coated specimens which had been tested at either of these temperatures and none was observed in coated or uncoated specimens tested at 1800° F. At 1900° F and 900 and 600 lb. per sq. in. the creep rate was virtually constant for the entire duration of the test for both alloys, but at 1800° F and 2200 lb. per sq. in. the initial creep rate was comparatively low. After about 20 to 30 hours the creep rate rapidly increased for a few hours and then became gradually less. At 1800° F and 2200 lb. per sq. in., the initial creep rate of coated specimens was well below that of the uncoated specimens and the creep curves of the coated specimens usually remained below those of the uncoated specimens during the first 20 hours. During a period of rapidly increasing creep rate

(*Continued in page* 338)


CREEP CURVES FOR 80/20 Cr ALLOYS AT 1975° F AND 600 psi
Lot A-Uncoated (Prefired 8 Min at 2050°F)
Lot C-Uncoated (Prefired 8 Min at 2050°F)
Lot A-Ceramic Coated With NBS No N-143
Lot C Ceramic Coated With NBS No N-143
CREEP IN PERCENT
TIME — HOURS

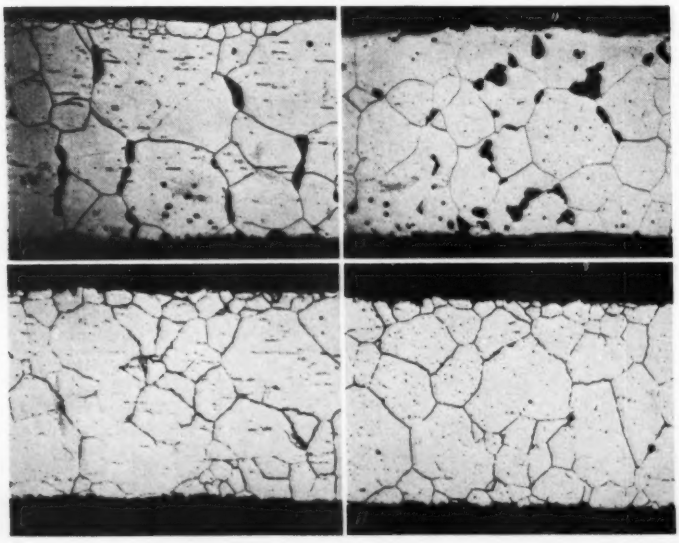


Fig. 1 (*left*).—*Photomicrographs of cross-sections of fired coated and uncoated specimens. Uncoated specimens show considerable void formation, while little or no void formation occurred in the coated samples. Sections were cut both transversely across and longitudinally with the applied stress. Specimens are* 0·010 *in. thick.* (*a*) *Uncoated, longitudinal,* 5·6 *per cent. elongation.* (*b*) *Uncoated, transverse,* 5·6 *per cent. elongation.* (*c*) *Ceramic coated, longitudinal,* 3·7 *per cent. elongation.* (*d*) *Ceramic coated, transverse,* 3·7 *per cent. elongation. Specimens,* 80/20 *Ni/Cr alloy. Test conditions* 600 *lb. per sq. in.,* 1975° *F,* 100 *hr.*

Fig. 2 (*above*).—*Creep curves for* 80/20 *Ni/Cr alloy, tested at* 600 *lb. per sq. in. and* 1975° *F.*

CURRENT MILL-ROOM PRACTICE

by S. H. RYDER, B.Sc., A.R.I.C., A.I.M.

(*A paper presented to the Annual Conference of the Institute of Vitreous Enamellers, Brighton, October 4 & 5, 1956*)

Synopsis

This paper deals firstly with the general factors controlling the wet-milling of materials in ball mills, after which a short review is given of two typical large American enamel milling plants. Finally, special attention is directed to methods of measuring the fineness of milled enamels, viscosity measurement, the estimation of enamel application weight and a short report on the use of high-density grinding balls.

BASIC DATA FOR MILLS

THE GENERAL consensus of opinion and practice for the wet-milling of materials in ball mills can be summarized as in Table I, while a schematic representation of the spatial distribution of balls, charge and water is shown in Fig. 1.

Pebble or Ball Loading

Ball size distributions usually conform to the proportions 20 per cent. small, 60 per cent. medium, 20 per cent. large, the actual diameters being dependent on the mill diameter but within the range of 1 to 3 in. diameter.

Current practice favours, in general, the use of smaller balls giving for the same weight an increased ball count and, therefore, a greater number of surface contacts, together with slower wear and increased ball surface area. This trend towards the use of smaller balls has been accelerated by the introduction of high-density balls, which are being increasingly advocated, particularly in the U.S.A. (this trend is referred to later in this paper).

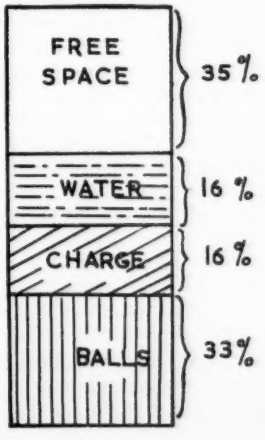


Fig. 1.—Schematic representation of mill load.

TABLE I

Internal mill volume	100	per cent.
Apparent pebble or ball volume	55	,,
True pebble or ball volume ...	33	,,
Apparent charge volume ...	25	,,
True charge volume	16	,,
True water volume	16	,, *
Total true occupied volume ...	65	,,

* i.e. 40 per cent of charge wt. for frit of sp. gr. 2.5 gives slip of sp. gr. 1.75

The total apparent pebble volume should normally be 55 per cent. of the total mill volume and, as the free space or voids between the pebbles are 40 per cent. of the total apparent pebble volume, the true pebble volume is (55-22)=33 per cent. of the mill volume.

It is of interest to note that the theoretical percentage of voids for spheres of uniform size arranged in a close-packed hexagonal structure to give the tightest packing is 31 per cent.

A close-packed hexagonal structure has an axial ratio, *i.e.*, height of the unit=layer 1 to layer 3÷length of side of equilateral triangles in basal plane, of 1·732 ($\sqrt{3}$). The total volume, therefore, occupied by n spheres of unit radius is $n \times 2 \times \sqrt{3} \times \sqrt{3}=6n$. As the true volume of the n spheres is $4\pi n=4{\cdot}19n$, the percentage of voids is

$$\frac{6-4{\cdot}19}{6} \times 100=31 \text{ per cent.}$$

The use of mixed pebble sizes rather than a uniform pebble diameter should in theory decrease the void space equivalent to maximum packing which would, therefore, be less than 31 per cent. It is obvious that maximum packing does not occur, as practical volume checks on the mill pebble loadings confirm this accepted ratio of 40 per cent. voids.

Charge Weights

The normal frit charge weight is 25 lb. per cubic foot of total mill volume which, for frit of 2·5 sp. gr. is equivalent to a true solid charge volume of 16 per cent. but an original "apparent" charge volume of approximate 25 per cent. of the mill volume.

Mill Water

The weight of water should normally be 40 per cent. of the charge weight (for frit of 2·5 sp. gr.), which is equivalent to 16 per cent. of the total mill volume. These proportions of frit and water will give a ground slip of 1·75 sp. gr. Normal U.S.A. practice for grinding slip density is 1·75 to 1·80 sp. gr.

Mill Temperatures

Vielhaber(1) states that if a mill runs too hot during grinding, enamel faults which can follow include streaks of bubbles during firing. The alkalis in the mill water may combine with CO_2 from the air to give carbonates which then decompose during firing and evolve gases.

Particularly when grinding in larger mills, it is most important to watch the temperature, a maximum for which is variously stated to be between 90 and 100° F. The most efficient method of avoiding overheating is to use a water-cooled mill but, where this is impossible or undesirable, the addition of excess mill water will reduce slip viscosity, power consumption and slip temperature, but will increase grinding time.

Mill Speeds

A long accepted formula for mill speeds is 65 per cent. of the critical speed, *i.e.*, $\frac{0{\cdot}65 \times 54{\cdot}18}{\sqrt{R}}$

R being the radius in feet.

In the case of all except, perhaps, the smallest size mill, this is a good basis on which to work. Table II gives the relationship between internal mill diameter, critical speeds and working speeds.

Energy Efficiencies of Commercial Ball Mills

A practical assessment of the energy balance of kinetic, heat and surface energy of commercial mill installations(2) has roughly confirmed the following approximate thermodynamic efficiency formula:—

$$\text{Percentage Energy Efficiency} = 100\left(1 - \frac{\text{Thermal Energy Output}}{\text{Kinetic Energy Input}}\right)$$

The highest energy efficiency is obtained therefore, when the ratio of heat produced to power consumed is a minimum. Thermodynamic efficiencies appear to vary from 10 to 19 per cent. and, therefore, 81 to 90 per cent. of the total energy input is converted to heat—hence the importance of water-cooling large mills.

TABLE II

Internal Dia. ft.	in.	Critical Speed r.p.m.	Working Speed r.p.m.
1	0	77	50
2	0	54	35
2	6	48·5	31·5
3	0	44	28·5
3	6	41	26·5
4	0	38	25
4	6	36	23·5
5	0	34	22
5	6	32·5	21
6	0	31	20

Salts in Mill Water

G. H. Spencer-Strong and others(3) have stated that many difficulties such as scumming, pitting, variation of set, etc., can be traced to the water supply. Plant is now available to produce large quantities of "demineralized" water continuously and economically by ion exchange. It is claimed to be comparable in quality with distilled water, the cost being only a small fraction of that of distillation.

Typical Layouts of some large American Enamel Milling plants

G.E.C. Plant at Alliance Park, Kentucky.

The mill room is three stories high. All raw material arrives in sacks and is palletized and elevated to the third floor for batch weighing, after which it is discharged directly into hoppers located above each mill.

The mills, which are on the first floor, are charged by opening the chutes under each hopper. Groundcoat is ground on one side of the mill room, covercoats on the other. These are four 6,000-lb., two 3,000-lb. and two 1,500-lb. mills, the average grinding cycle being 4½ hours, giving a total capacity of 15 tons per 4½ hours.

All mills are Patterson water-cooled, lined with porcelain blocks and charged with high-density balls. Grinding densities are somewhat higher than the specific gravity of the slip for application which are 1·62 for groundcoat, 1·70 for groundcoat reinforcing spray and 1·75 for covercoats. Ground slurry is passed over a magnetic separator and through a coarse screen into a sump, whence it is pumped into stainless-steel-lined storage tanks, equipped with stainless-steel agitators. When required for use, it is transferred into 50-gallon movable pressure tanks for spraying, or open buggies for dipping.

Demineralized water is used throughout to maintain uniformity of slip characteristics.

Westinghouse plant at Columbus, Ohio.

In this $45-million plant materials arrive in pre-weighed palletized sacks and are elevated to the

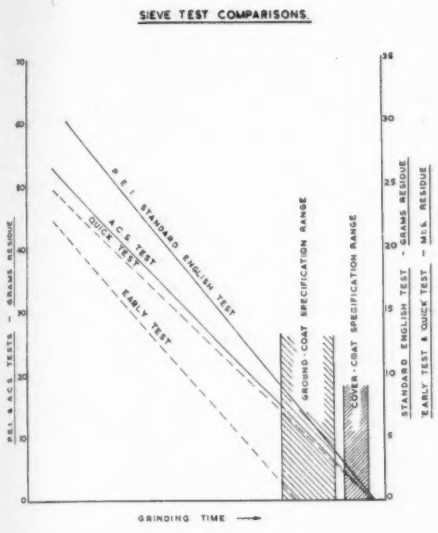


Fig. 2.—Comparison of efficiencies of sieve tests.

floor above the mill room, where the mill additions are weighed and charged together with the frit through stainless-steel funnels into the mills. There are four 6,000-lb. Patterson mills, which are not water-cooled and, therefore, are probably not using high-density balls. Demineralized water is metered into the mills which, after grinding, discharge the slip into the main storage tanks. The slip is then passed through a Rotospray sieve and a Ferro filter into 500-gallon agitated pressure vessels from which it is conveyed through stainless-steel pipes, water-cooled where they pass near to the furnaces, to the spray booths.

Fineness Tests

There are a number of tests used in the industry, all based on the amount of residue, measured by weight or volume, on a 150 or 200 B.S.S. sieve, five of which are listed in Table III. A plea could well be made for standardization of these tests and also for their extension into the fine particle size range.

Fig. 2 illustrates the relative results obtained by these five fineness tests during the complete grinding cycle of a covercoat and a groundcoat. The two shaded areas denote the general groundcoat and covercoat fineness specification ranges and show that the "Early" test measuring residue on a 150-mesh is quite ineffective in controlling finenesses in the specification ranges.

A very approximate statistical examination of the numerical results given by these five different test procedures applied to a rather limited number of samples gave the figures for percentage average

TABLE III

Description	Slip Volume	Test Sieve	Residue measured as:
1. "Early" Test	50 mls.	150 mesh	Dry volume in mls.
2. P.E.I. Test	100 mls.	200 mesh	Dry weight in grams.
3. A.C.S. Test	Vol. ctg. 100 gm. solids	200 mesh	Dry weight in grams.
4. Quick Test(°)	50 mls.	200 mesh	Wet volume in mls.
5. Standard English Test	50 mls.	200 mesh	Dry weight in grams.

deviation and maximum deviation shown in Table IV.

These results indicate that "volume" measurement of the residue is not as satisfactory as weight measurement.

Fig. 3 shows the relationship between the four tests using a 200-mesh sieve. It is based on typical slip densities for groundcoat and covercoat (1·75 for groundcoat and 1·78 for covercoat) and ascertained factors for conversion of wet residue volume to dry weight in the "Quick" test (1 ml. wet groundcoat residue=1·27 gm. dry weight. 1 ml. wet groundcoat residue=1·25 gm. dry weight)).

For the investigation and also the control of grinding, more precise methods of particle size measurements are available. A 200-mesh test can only indicate the percentage of particles greater than 0·0030 in. (76 microns) dia. A 300-mesh will give information regarding particles with diameters greater than 0·0021 in. or 53 microns. A rapid and very popular method of particle fineness measurement used in the pottery industry and

Fig. 3.—Relationship between results of sieve tests.

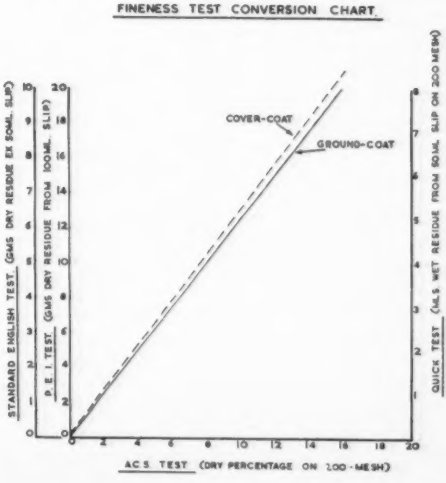

FINENESS TEST CONVERSION CHART
COVER-COAT
GROUND-COAT
STANDARD ENGLISH TEST (GMS DRY RESIDUE EX 50ML. SLIP)
P.E.I. TEST (GMS DRY RESIDUE FROM 100ML. SLIP)
QUICK TEST (ML'S WET RESIDUE FROM 50ML. SLIP ON 200 MESH)
A.C.S. TEST (DRY PERCENTAGE ON 200-MESH)

TABLE IV

Test	Average Deviation per cent.	Maximum Deviation per cent.
P.E.I. and English Test	5·2	14
A.C.S. Test ...	7·5	15·5
"Quick" Test ...	8·4	26
"Early" Test ...	12	33

based on sedimentation principles is the Hydrometer method developed by Webb and Ratcliffe[5]. A determination of fineness by this method takes about 40 minutes and is normally reported as percentage less than 10 microns. The hydrometer method can also be used to obtain a complete size distribution curve for ground materials, information which can be very useful in any detailed investigation of grinding performances or product variability.

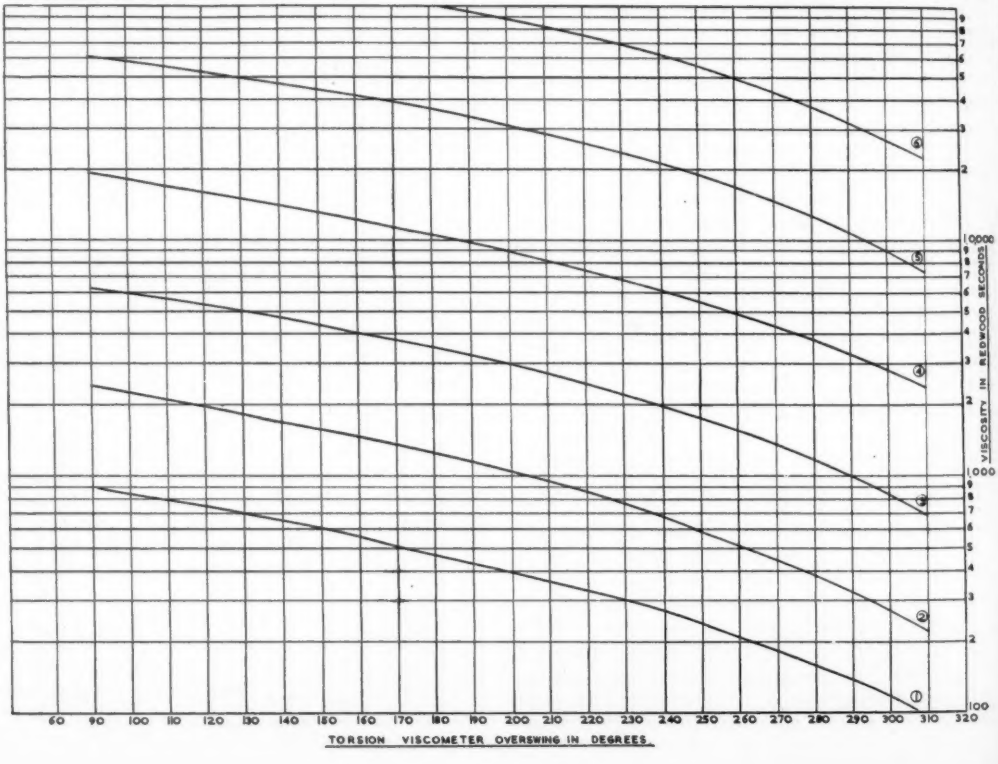
Fig. 4.—Curves showing relationship between viscosity in Redwood seconds and readings on torsion viscometer for various combinations of cylinder and torsion wire.

Curve No.	1	2	3	4	5	6
Cylinder dia. in. ...	1⅛	1⅛	1⅛	1⅛	½	½
Torsion wire gauge s.w.g. ...	36	30	36	30	36	30

Viscosity

The alleged viscosity of an enamel is usually estimated by timing the flow of a fixed volume of slip (200 cc.) through a standard orifice (usually 13/64 in.), at the base of a standard brass cylinder. This test is considered adequate for routine checking of enamel batches.

For any detailed investigation of fluid properties of enamels, the use of the Gallenkamp Technico Torsion Viscometer has much to commend it. This instrument, which is widely used in the pottery industry for routine control of glazes and body slips, is simple and rapid in operation. It consists of a metal cylinder, suspended by a torsion wire so that it is free to rotate in the fluid under investigation. The initial position is so arranged that the wire has one complete revolution of torsion *i.e.*, 360°. The cylinder is released by operation of a spring catch and rotates in the fluid, the angle of "overswing" (the number of degrees of rotation past the zero position) being taken as a measure of the viscosity of the fluid. A combination of three different cylinder sizes with two different gauges of torsion wire enables measurements to be taken over a very wide viscosity range and graphs are provided showing the approximate relationship between "degrees overswing" for different cylinder



and wire combinations with conventional viscosities in Redwood Seconds (Fig. 4). In actual practice, a single combination of one cylinder and one torsion wire will almost certainly cover the range of viscosities found in enamel slips.

The torsion viscometer can also be used to measure thixotropy, a most important fluid property of many suspensions, best defined as the increase in viscosity on standing. Thixotropy is measured by taking viscometer readings:—

1. Immediately after agitating the sample.
2. After allowing the sample to stand for a definite period of time, usually 60 seconds, but sometimes for a longer period.

Thixotropy, thus defined as the increase in viscosity with time, is, therefore, indicated by a reduction in degrees overswing on the torsion viscometer. There are indications that vitreous enamel slips can show "negative" thixotropy or "dilatency" *i.e.*, a decrease in viscosity on standing indicated by an increase in degrees overswing on the viscometer.

It is the author's belief that this instrument would be most useful in the examination of enamel slips, both for investigation of grinding conditions and comparison of electrolyte additions used to set-up the slip as well as for routine control of enamel consistency.

Enamel Application Weight

The British Ceramic Research Association have developed a thickness gauge for use in the pottery industry for measuring the application thickness of glazes before firing, recommended limits for which are:

Bone china 0·008 to 0·012 in.
Earthenware 0·010 to 0·020 in.

TABLE V

MILL Size	Vol. Cub. Ft.	BALLS Wt. (lbs.)	BALLS Vol. %	FRIT CHARGE Wt. (lbs.)	FRIT CHARGE Vol. %	FRIT CHARGE Enamel Type	MILLING Time (hrs.)	MILLING Fineness	ENAMEL TEMP. (° F)	MILL SPEED R.P.M.	MILL SPEED Critical Speed x 0·65
4 × 5	18	2600	47·5	1000	14·6	Gr.C.	3·75	7—9	60	13·75	26·5
,,	,,	3200	58·5	1000	14·6	C.C.	4·5	0·5	94	25	,,
,,	,,	3200	58·5	1000	14·6	Gr.C.	2·5	7—8	88	25	,,
,,	,,	3000	55	1000	14·6	Gr.C.	2·5	5—7	—	24·5	,,
,,	,,	3070	56	1300	19·0	Gr.C.	4·5	8	100	24	,,
4.5 × 4.5	50·28	3600	57·5	1300	15·8	C.C.	7·5	0·5	100	18	25
5 × 4	55·68	4000	57·5	1500	16·9	C.C.	5·5	3	100	21	23·5
5 × 6	87·5	7000	64	2500	18·3	C.C.	10·5	0·5	90	21	23·5
,,	,,	7500	68·5	2500	18·3	C.C.	8·5	0·5	90	21	,,
,,	,,	7100	65	2500	18·3	C.C.	8	0·5	90	21	,,
6 × 4	83·3	4500	43	1500	11·5	Gr.C.	3	7	100	23	21
6 × 5	106·95	7680	57·5	2000	12·0	C.C.	2·25	3	100	24	21
,,	,,	8100	60·5	2500	15·0	C.C.	3	3	96	19	,,
,,	,,	8100	60·5	2600	15·5	C.C.	5·25	3	100	19	,,
,,	,,	8100	60·5	2600	15·5	C.C.	5·25	3	102	19	,,
,,	,,	8100	60·5	3100	18·5	Gr.C.	4·5	5	92	19	,,
,,	,,	7500	56	3000	18·0	Gr.C.	4·5	6	98	20	,,
,,	,,	7200	54	3100	18·5	Gr.C.	5	5—6	95	19	,,
,,	,,	7200	54	2300	13·7	C.C.	5	1—2	100	19	,,
6 × 6	130·7	7800	48	2000	9·8	Gr.C.	2·25	7	100	20	21
6 × 8	178·2	13000	58·5	4100	14·7	Gr.C.	3·5	5	90	19	21
,,	,,	10500	47	3000	10·8	Gr.C.	3	7	100	19	,,
8 × 6	243	17500	58	6000	15·8	Gr.C.	5	5—6	100	13·75	18·25
,,	,,	15000	49·5	6000	15·8	Gr.C.	4	5—6	95	13·75	,,
,,	,,	15500	51	6000	15·8	C.C.	4	3	105	19	,,
,,	,,	15500	51	6000	15·8	Gr.C.	3·5	6	100	19	,,
,,	,,	15500	51	6000	15·8	Gr.C.	4·5	6·5	99	19	,,
,,	,,	17500	58	5500	14·5	C.C.	6	1—2	100	13·75	,,
,,	,,	15000	49·5	5500	14·5	C.C.	6	1—2	95	13·75	,,
GROUP AVERAGES:											
4 × 5	43·87	3010	55	1060	15·4	—	3·5	—	—	23·5	26·5
5 × 6	87·5	7200	66	2500	18·3	C.C.	9	0·5	90	21	23·5
6 × 5	106·95	7750	58	2650	15·8	—	4·25	—	—	20	21
6 × 8	178·2	11750	53	3550	12·7	Gr.C.	3·25	6	95	19	21
8 × 6	243	16000	53	5850	15·4	—	4·75	—	—	16	18·25

Notes: (1) Mill volumes calculated assuming 3-in. lining blocks.

(2) Ball volumes based on alumina balls with s.g. 3·4, which with normal packing of 41 per cent. void volume are 125 lb. per cubic foot of ball volume.

(3) Frit volumes based on frit s.g. 2·5, given as percentage of total mill volume.

(4) Frit fineness units not stated, but probably percentage on 200-mesh.

After firing, the glaze thickness is about half that of the unfired glaze. This instrument (Fig. 5), which is rapid, simple and accurate in operation, would undoubtedly be very useful to enamellers in checking thickness variation in production. Details of the instrument are available from the Director, B.C.R.A., Queens Road, Penkhull, Stoke-on-Trent.

High-density Grinding Balls

Table V gives a survey of data obtained from a number of American plants[6], using alumina grinding balls of specific gravity 3·4 and covering mills ranging from 3 to 8 ft. diameter.

Apart from the general interest of the information presented on "occupied" mill volumes for ball charge and frit, grinding rates are quite fast. Vernetti's conclusions from his review are that the use of high-density balls:—

1. Have reduced grinding times by between 30 and 60 per cent. for groundcoat and by up to 40 per cent. for covercoat.
2. Have reduced ball wear from between 5 and 10 lb. per 1,000 lb. frit for porcelain balls to about 1 lb. per 1,000 lb. frit for alumina balls.
3. Have, in general, given longer lining life, lining wear being usually more uniform and free from grooving.

Table VI[7] illustrates a most important difference between high-density alumina balls and the conventional flint or porcelain grinding media.

It is seen that, whereas in air alumina balls are only 36 per cent. heavier than porcelain, in slip of 1·7 sp. gr. they are effectively about $2\frac{1}{8}$ times as heavy or 112 per cent. heavier than ordinary balls.

The higher the specific gravity of the enamel, the greater the difference in "working weight", indicated in the column headed "Relative Weight in Slip". Thus far greater effective working weight is mainly responsible for the faster grind but, also, it enables small ball sizes to be used. Thus, taking for example a 5 ft. dia. × 6 ft. long mill of total volume 92 cu. ft. and apparent pebble volume 51 cu. ft. (55 per cent. of 92 cu. ft.), the weight of alumina balls per cu. ft. of apparent volume is

Fig. 5.—B.C.R.A. Thickness gauge.

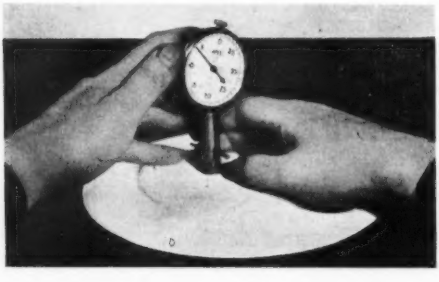


TABLE VI

Type of Ball	Sp. Gr.	Relative weight in air	Sp. Gr. difference against slip of 1·7 Sp. Gr.	Relative weight in slip
Porcelain and Flint ...	2·5	100	0·8	32
Alumina ...	3·4	136	1·7	68

125 lb. (*i.e.*, $62{\cdot}5 \times 3{\cdot}4 \times {\cdot}59$), assuming 41 per cent. voids in the ball packing. Then:—

(*a*) Using normal size distribution (20 per cent. small, 60 per cent. medium, 20 per cent. large by weight) gives the results as tabulated in Table VII.

(*b*) Using $1\frac{1}{4}$-, $1\frac{1}{2}$- and 2-in. dia. balls, the figures are as set out in Table VIII.

Thus, using the smaller ball sizes, there are more than twice as many balls and, hence, many more surface contacts. There is also over 30 per cent. more ball surface area, 1,003 sq. ft. in (*a*) and

TABLE VII

Ball dia. in.	No. of Balls per cu. ft.	No. of cu. ft. in charge	Ball wt., lb.	No. of Balls in charge
$1\frac{1}{4}$	508	10	1,250	5,080
2	220	31	3,875	6,820
$2\frac{1}{2}$	111	10	1,250	1,110
		51	6,375	13,010

1,310 sq. ft. in (*b*). A further advantage of using smaller balls is that they wear slower, because of the decreased striking force on impact.

Summarizing, it is said that, to get best results with high-density balls, the following points should be observed:—

1. Slow down the ball action by increasing the frit charge up to 15 per cent. of normal.
2. If the extra capacity is not wanted, decrease the mill speed to between 60 per cent. of the critical speed for small mills to 40 per cent. of the critical speed for large mills.
3. Keep the total apparent volume at 55 per cent. of the total mill volume. This involves using 40 per cent. more weight of high density balls, compared with porcelain.

(*Continued in page* 337)

TABLE VIII

Ball dia. in.	No. of Balls per cu. ft.	No. of cu. ft. in charge	Ball wt., lb.	No. of Balls in charge
$1\frac{1}{4}$	1,000	10	1,250	10,000
$1\frac{1}{2}$	508	31	3,875	15,478
2	220	10	1,250	3,300
		51	6,375	28,778

TIN RESEARCH INSTITUTE CELEBRATES "First 25 Years"

IN January, 1932, the first meeting of the International Tin Research and Development Council was attended by delegates from the tin-producing countries of the world with the aim of making plans for an organization to increase world tin consumption by research and development. In August of the same year a director of research was appointed, followed by the appointment of a director of industrial development.

Prior to 1938 tin research was "farmed out" in University and other laboratories, a course of action that tended to make the research academic and insufficiently related to industrial needs, but in that year the laboratories of the Tin Research Institute at Greenford, Middlesex, were inaugurated.

The provision of a laboratory devoted solely to tin research allowed the building up of a team of "tin conscious" experts. At this time, however, the tin consumers for whom the research was being carried out, albeit paid for by the producers, viewed with understandable suspicion the attentions of an international body on behalf of the producers. It was necessary, therefore, to win the confidence of the consumers, a task made easier by the second world war, which broke down barriers so effectively.

Due in many cases to the shortage of tin, manufacturers were faced with new problems, which were brought to the Institute, so forging a link of goodwill and confidence which has grown ever stronger.

During the post-war years the organization has really come to fruition, and in 1951 the Greenford laboratories were remodelled and extended. Of great importance also was the decision to provide centres of technical service for tin in the world's important tin-consuming countries.

The International Tin Research Council, as it is now called, does not narrowly define the function of research but includes in that concept all the technical development services which are needed to ensure that scientific investigations flow through into industrial practice. As is well known, the extent to which this has been achieved is great, and full use has been made of technical publications, lectures, conferences, correspondence, exhibitions, films, laboratory demonstrations to disseminate information.

During 1956, for example, the number of technical publications sent out from the Institute exceeded 150,000 and they were distributed in 65 different countries. In the same year about 50 lectures on various aspects of tin were organized, covering several countries, and some thousands of serious technical enquiries from tin users were dealt with.

Current Research

Hot Tinning

In addition to the advice given by the Institute regarding the design or modernization of hot-tinning plant, a survey has been made of a number of blended tinning oils developed for use as alternatives to the naturally occurring oils. Some of these oils have good heat resistance and long life, and may be particularly useful for use in flow-brightening processes. A study has also been made of the effects of various annealing atmospheres on the structure and "tinnability" of cast iron. Indications are that air annealing, followed by a special pickling treatment, may make possible satisfactory coatings with bond strengths as high as 5 tons per sq. in.

Some preliminary work has also commenced on the continuous hot-dip tinning of strip and apparatus has been constructed for this purpose. The continuous hot-dip tinning of both copper and steel strip and wire is being investigated.

Soldering

A programme of tests to study the effects of duration and temperature of storage on the solderability of tin and tin-alloy coatings on a range of metals has been progressed. All specimens have been tested up to the one-year stage of storage at 25° C. and 50° C.

Tinplate

Tinplate accounts for about 40 per cent. of the world's annual tin consumption, and the laboratory's apparatus for the production of experimental electrolytic tinplate has supplied specimens for many investigations. Testing methods for tinplate have been standardized, particularly in connexion with the coulometric determination of tin and tin-iron alloy coating thicknesses.

The effect of various passivating treatments, including the "Protecta-tin" process, have been further investigated, particularly as regards the canning of milk.

Work has also been carried out on the formation of useful or harmful oxide films on tinplate. Among the more interesting results are the extremely rapid initial growth of the films in air on freshly cleaned surfaces, the strong effect of atmospheric humidity on the rate of growth in air and the rapid attainment of a limiting film thickness in some chemical passivation treatments.

Tin-nickel electroplate is used on trumpet valves and trombone slides manufactured by Boosey and Hawkes Engineers Ltd.

Apparatus has also been developed for the flow brightening of tin coatings by means of an electric current which is passed through the coated strip for a controlled short period.

Electroplating

A practical process for the electrodeposition of bright tin has long been needed and a detailed study has been made of the use of wood tar as a brightening agent.

The commercial applications of tin-zinc alloy coatings continue to increase, among the new applications being hydraulic pit props. A modified process in which an organic complexing agent is used instead of sodium cyanide in the electrolyte is showing promise and experience of its commercial possibilities is being gained.

Several more firms have adopted tin-nickel alloy plating as a durable finish for their products, and further tests on undercoatings for tin-nickel alloys on steel have been carried out. Some preliminary work has also been effected on the use of tin-nickel alloy as an undercoat for chromium plating. It is notable that the preliminary difficulties of the tin-nickel plating bath, *i.e.*, the evolution of HF, have now been overcome so that fume extraction is now far less critical. A particularly interesting application of tin-nickel alloy plating is that of the valves and slides of musical instruments of the "brass" family, where its resistance to corrosion and its low frictional properties show to considerable advantage.

Continuous Casting

The Institute's method of continuously casting bronze rods and tubes has now been adopted by several firms. The original apparatus in the laboratory has now been redesigned for work on the continuous casting of phosphor-bronze billets suitable for rolling to strip for springs and similar applications. The casting of flat sections is more difficult than the casting of rods and tubes in that it is difficult to design a water jacket with flat faces that will remain free from distortion.

This problem has been circumvented by applying bottom cooling to the die. A film has been made of the continuous casting process.

Other Work

Powder metallurgy (*e.g.*, the production of titanium-tin alloys), additions of tin to stabilize the pearlite in cast iron, die casting of ball-point pen nibs, and corrosion studies are among the many other fields investigated.

Organotin Compounds

Although the metallurgical uses of tin are old, during the last 40 years enormous new chemical industries have grown up which so far have used very little tim. Clearly, tin is more likely to be assimilable in chemical industries if presented in a chemical form and especially in organic form. Organotin compounds, defined as compounds containing a direct tin-carbon linkage, can be regarded as organic chemical compounds in which at least one atom of carbon is replaced by tin. The purpose of the research is to produce materials containing tin in such a form that they can be used in spheres far removed from metallurgical applications, *e.g.*, for fuels, lubricants, detergents, paints, plastics, insecticides, fungicides, weed killers, pharmaceutical, textiles and rubber.

The centre of organotin work is at the Organisch Chemisch Institut, T.N.O., Urtecht, Holland. The Council also supports researches at a number of other centres.

The year has been rich in research results and special mention may be made of a new method of synthesizing organotin compounds through the substituted tin hydrides.

Evidence of the non-toxicity of dioctylin compounds has heightened interest in their use as stabilizers for polyvinyl chloride plastics.

The first Conference on Organotin Chemistry ever to be held publicly was organized successfully in Paris.

An Examination of CONCENTRATION DIFFERENCES IN LEAD-FLUOBORATE PLATING BATHS

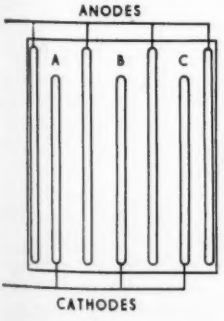
by Gunnar GABRIELSON ★

Introduction

ALTHOUGH the phenomenon of concentration differences at different levels in plating solutions has not received much attention in the literature, it is a well-known fact to the practical working plater that some electroplating solutions, *e.g.*, the chromium plating bath and especially the lead-fluoborate bath, have a marked tendency to be more concentrated at the bottom of the plating tank than at the top. This depends on the manner in which the lead-fluoborate bath is prepared. This bath is manufactured as a highly concentrated solution, which, before using, is diluted with water. During dilution the concentrate sinks to the bottom of the tank and is only partly mixed with the water, and because of this it is necessary to stir the solution vigorously in order to get it homogeneous. However, even after stirring the solution is very often more concentrated at the bottom than at the top of the plating tank, even if the bath has been used for a long time. It is the aim of this paper to examine quantitatively these concentration differences in the lead-fluoborate bath. It should be pointed out, however, that the solutions which show this behaviour are all rather concentrated.

★ *AB Tudor, Nol, Sweden.*

Fig. 1 (*below*) *Fig.* 2 (*right*)



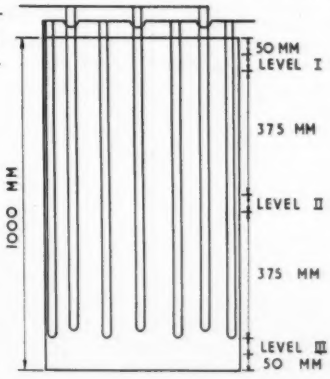


Fig. 1.—Diagram of plating tank from above, showing compartments A, B and C.

★

Fig. 2.—Diagram of side elevation of plating tank showing various levels, I II and III mentioned in text.

The effects of these differences in the concentration at different levels appear principally in two ways. First, the quality of the deposit and its thickness are dependent on the position of the article to be plated in the plating tank. Second, it is very difficult to obtain accurate results when analysing the solution if the samples are not taken with the utmost care so that they are truly representative of the solution in question. If this is not done the corrective additions to the bath must be wrong, as either too many or too few chemicals are added, depending on whether the sample is taken at a level in the bath, where the solution is too diluted or too concentrated.

Experimental

As has been mentioned above, very little, if any, information can be had from the literature regarding the concentration differences at different levels in electroplating solutions. It was therefore considered advisable to perform an analytical investigation with regard to this, the solution investigated being a lead-fluoborate bath of common type with the following composition:

Lead: 165 grams per litre;
Free fluoboric acid: 40 grams per litre;
Excess boric acid: 18·5 grams per litre;
Gelatin: 1·0 gram per litre.

The bath was operated at room temperature at 3·5 volts and a total current of 120 amp., which corresponds to a current density of about 1 amp. per sq. dm. The plating tank was of rubber-lined steel, with the following dimensions: length, 700 mm. (27·5 in.); breadth, 600 mm. (23·5 in.); height, 1,000 mm. (39 in.). In the tank there were four rows of anodes and three with articles to be lead plated. The three "compartments" formed by the anode rows were named A, B and C, according to Fig. 1. In each of these "compartments" the solutions were analysed at three different levels, namely at a depth of about 50 mm. below the surface of the solution, at half the depth of the bath

TABLE I

Level	Lead content, grams per litre			Mean Value
	Compartment			
	A	B	C	
I	147·6	144·9	148·3	146·3
	146·2	143·2	147·3	
II	151·0	149·0	150·7	151·1
	151·3	151·7	152·7	
III	238·5	242·7	240·9	240·5
	238·2	241·2	240·9	

and at the zone between the anodes and the bottom of the tank, as is seen from Fig. 2. These three levels were named I, II and III respectively (Fig. 2).

In the first experiments the samples were taken when the bath was operating. The samples were analysed only for lead content, which was determined through precipitating and weighing as lead sulphate. The results are shown in Table I; as a control the lead content was determined twice in every sample; each determination is shown in the table; as is seen the precision of the analyses is high.

In the second experiment the samples were taken from the same lead-fluoborate bath early on Monday morning, when the bath had been at rest from noon on Saturday, *i.e.*, about 40 hours. As before, the lead content in the solution was determined through precipitating and weighing as lead sulphate. The results are presented in Table II; also in this case the lead content was determined twice in every sample, as is shown in the table; as before, the precision is high.

In the experiments described above the samples were taken by means of a glass tube about 1,100 mm. long used like a pipette.

TABLE II

Level	Lead content, grams per litre			Mean Value
	Compartment			
	A	B	C	
I	152·1	154·8	154·1	153·4
	153·4	154·1	152·0	
II	155·8	157·2	159·9	157·3
	155·1	158·5	157·5	
III	237·5	242·3	240·6	239·7
	236·1	240·6	241·2	

In the experiments shown in Table II when the solution had been at rest for about 40 hours, a sample representative for the whole bath was also taken by the following procedure: After the lower end of the tube with the upper end open had been immersed in the solution to a level of about 50 mm. above the bottom, a finger was placed over the upper end and the sample was withdrawn. Such a sample was taken at several locations in the tank. By analyzing these combined samples as before, through precipitating and weighing the lead as lead sulphate, a mean value of the lead content in the bath was obtained. The values found in two analyses were 165·7 and 167·1 grams lead per litre respectively, *i.e.*, a mean value of 166·4 grams lead per litre. Comparing this with the mean values from Table II and assuming that the lead content in the upper 100 mm. of the solution is 153·4 grams per litre, in the following 800 mm., 157·3 grams per litre and in the last 100 mm., 239·7 grams per litre, a mean value is:

$$\text{grams per litre lead in the bath} = \frac{153{\cdot}4 \times 100}{1{,}000} + \frac{157{\cdot}3 \times 800}{1{,}000} + \frac{239{\cdot}7 \times 100}{1{,}000} = 165{\cdot}2 \text{ grams per litre}$$

This result is in very good agreement with the result from the representative sample.

Discussion

As can be seen from Tables I and II satisfactory agreement is obtained between the lead content at different levels in the lead-fluoborate bath, either when the solution is electrolyzed or is at rest. From the top of the solution there is only a slight increase in the concentration until the part of the solution under the anodes is reached, *i.e.*, level III. The lead content is only increased 4 to 5 grams per litre from the top to the middle of the tank, but the difference between the top and the bottom section is 85 to 95 grams lead per litre. This must depend upon the fact that in the bulk of the solution the bath is stirred through immersing and removing the articles to be plated, so that the concentration differences are largely levelled. At the bottom, however, the solution is unstirred and as the diffusion rate is normally very low, this part of the solution remains at a very high concentration.

It may in this connexion be convenient to discuss diffusion in some detail. Diffusion means that if a solution has the same temperature and pressure but different concentrations in different parts, this concentration difference is levelled. The diffusion rate is inversely proportional to the viscosity of the solution and the radii of the diffusing ions. As the viscosity of the lead-fluoborate bath is rather low (experimental values were found to be 0·98 and 1·04 centipoises at the top and the bottom of the solution respectively) this cannot explain the tendency of

settling described in this paper. On the other hand, it is possible that the radii of the diffusing ions are large, *i.e.*, that complex or strongly hydrated ions are formed in the lead-fluoborate solution. This effect, however, is in all probability considerably less than the effect of the relatively low operating temperature (about 20° C). The diffusion rate is greatly increased with increased temperature.

Because of the great concentration differences in a lead-fluoborate bath (*see* Tables I and II) it is of the utmost importance that the samples to be analyzed are taken very carefully. If, for example, the glass tube is shut by the finger at the upper end when immersing in the solution and the lower end reaches the highly concentrated bottom layer, then the tube is filled with this solution when the finger is removed. The result of the analysis in this case is, therefore, entirely erroneous. On the other hand, if the sample is taken in such a way that it is representative of the whole solution, accurate results are obtained, as is seen from the above.

How to Avoid Concentration Differences

It is self-evident that in order to obtain deposits of high quality and to get accurate analytical control it is highly desirable that the solution is homogeneous. Therefore it is necessary to stir the lead-fluoborate bath in some way or other. In this investigation no experiments have been performed to study the effect of stirring, but some remarks about this may be quoted.

The two general ways of agitating plating baths are: (*a*) through air blowing and (*b*) through pumping the solution.

(*a*) *Air blowing*. Agitation by blowing air or some inert gas, *e.g.*, nitrogen, into a solution is a common method in the metal-finishing industry. The method seems, however, in this case to be rather unsuitable, as fluoboric acid is formed through reaction between hydrofluoric acid and boric acid according to the formula:

$$H_3BO_3 + 4\,HF \rightleftarrows HBF_4 + 3H_2O \quad . \quad . \quad . \quad . \quad . \quad (1)$$

It is possible that the formula of fluoboric acid is more complex, but for convenience the formula HBF_4 is employed. Hydrofluoric acid is very volatile and when the air is blown through the solution it may be that the hydrofluoric acid evaporates, *i.e.*, the equilibrium in equation 1 above is displaced to the left. There is indeed an excess of boric acid, as is seen from the formula of the lead-fluoborate bath, which counteracts the evaporation of hydrofluoric acid, but nevertheless the risk is there. Irrespective of the fact that this evaporation disturbs the chemical equilibrium in the bath, the hydrofluoric acid is very corrosive and injurious to inhale. Agitation of the fluoborate bath by air-blowing is therefore not to be recommended.

(*b*) *Pumping the solution.* Pumping is mainly used for the agitation of a plating bath and seems also to be the best method in this case. It is, however, necessary to be careful in the choice of material used for the pump, as the fluoborate baths are very corrosive. The materials recommended for plating tanks for these solutions are rubber- and polyethylene-lined steel and it seems to be convenient to have pumps in these materials, *i.e.*, steel pumps in which all parts that come into contact with the solution are rubber- or polyethylene-lined, or pumps entirely of polyvinyl chloride (PVC). Perhaps it may be necessary to use diaphragms in order to prevent the sludge formed at the lead anodes from lodging on the cathodes and causing roughness in the deposits.

As is seen in Tables I and II the lead-fluoborate bath is much more concentrated at the bottom than in the bulk of the solution. It seems, therefore, to be convenient to pump the solution through piping in the bottom of the tank to the top of the solution, in order to mix the bath thoroughly.

It was pointed out earlier that the diffusion rate was greatly increased with increased temperature. In an endeavour to get the solution homogeneous the temperature ought therefore to be as high as possible. The temperature generally recommended for the lead fluoborate bath is 20°-40° C. If possible the bath should therefore be operated at a temperature of 40° C.

Current Mill-room Practice

(*Continued from page* 332)

4. Use 20 per cent. small, 60 per cent. medium, 20 per cent. large balls.
5. Never exceed 2½ in. dia. even for the largest mills. It is better to use 2 in. as a maximum ball diameter.
6. Although most mills are adequately powered to grind with high density balls, power provision should be of the following order:—
   Mill 6 ft. dia. × 11 ft. long—50 h.p.
   Mill 6 ft. dia. × 7 ft. long—20 h.p.
   Mill 4 ft. dia. × 5 ft. long—10 h.p.
   Mill 2½ ft. dia. × 5 ft. long—5 h.p.
7. If necessary, water cool the mills and/or the bearings.

Acknowledgement is made to the Directors of C. E. Ramsden and Co. Ltd., Stoke-on-Trent, for their kind permission to present and publish this paper.

References

(1) Vielhaber, *Glas.-Email-Keramo Tech. Z.*, 39, 1951.
(2) Schellinger, A. K., and Lalkaka, R. D., "Approximation of the Energy Efficiencies of Commercial Ball Mills by the Energy Balance Method", *Mining Engng.*, 3, 523, 1951.
(3) Spencer-Strong, G. H. *et al*, "Modern Porcelain Enamelling", *Ceram. Ind.* 53, No. 1, 61, 1949.
(4) Biddulph, A., "Milling of Enamels", *Proc. I.V.E.*, VIII, 57, 1943-47.
(5) Webb and Ratcliffe. *Trans. B.C.S.*, 41, 51, 1941.
(6) Vernetti, J. B., *Cer. Ind.*, 62, 3, 70.
(7) *Ceramic Industry*, Feb., 1953.

Effect of Ceramic Coatings on Creep

(*Continued from page* 326)

(about 20 to 30 hours after the start of the test) coated specimens generally showed an even greater rate of increase than the uncoated; fracture of the coated specimens usually occurred during this period. One ceramic-coated specimen, which did not fail under test for more than 1200 hours, showed significantly greater creep after the first 100 hours than did the uncoated specimens.

Tests suggest that the N-143 coating is not sufficiently fluid at 1800° F to follow the deformation of the specimen when a stress of 2200 lb. per sq. in. is applied and it therefore cracks. Profuse cracking of the coating was observed in all of the coated specimens that failed in test at 1800° F and 2200 lb. per sq. in., but in no other specimens. Presumably, at higher temperatures the N-143 coating, being more plastic than at lower temperatures, was able to follow the deformation of the specimens at strain rates as high as those observed at 1800° F and 2200 lb. per sq. in.

Reference

Cuthill, J. R.; Richmond, J. C. and Tighe, N. J. *Jnl. Am. Cer. Soc.* (*in the press*)

Air Treatment Systems

(*Continued from page* 325)

top of process vessels into slotted ducts at the top. These slots extend fully on one or several sides of a vat and are about two inches wide.

The flexible exhaust tube method has been developed in recent years. It consists of flexible tubes having one end connected to an exhaust system. A slotted hood attached to the other end is shaped as required, and relatively small exhaust volumes are required.

The design of an efficient duct system is not an easy task. Calculations have to be based on certain co-efficients which have to be chosen by the designer according to his experience. To apply the right air velocities, pressures, suctions and to design the ductwork with a minimum of change of direction of air flow, to calculate the changes in pipe sizes, to lay out the branching out of a main duct into several branch lines, all require care in design. As a general rule main trunks and branch pipes should run as short and straight as possible. Any restrictions should be avoided in a piping system. For efficient sizing a careful computation of friction drop in ducting is necessary. The total friction loss in a ducting system is the friction drop in the most remote branch plus the drop in the various sections of the main duct, plus the pressure drop in the discharge pipe. Power consumption of fan motors depends on correct dimensioning of a system. The efficiency of a dust exhaust system depends upon its effectiveness in reducing the concentration of dusts, fumes, vapours and gases below the safe limits.

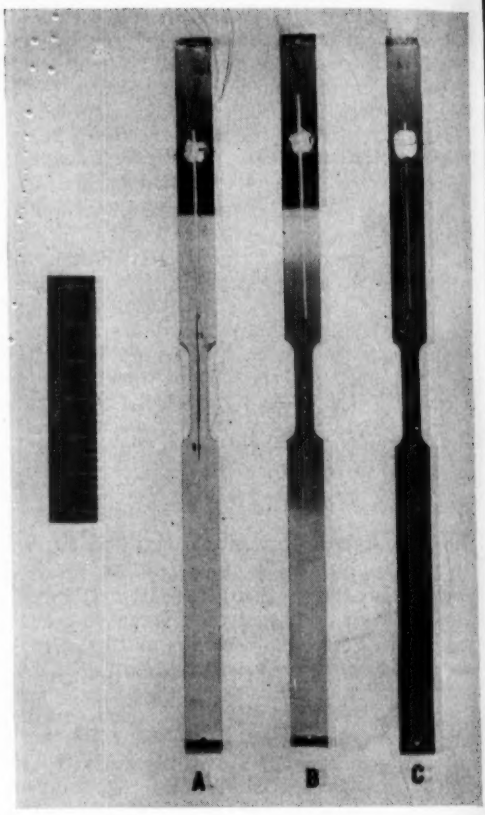


Fig. 3.—*Specimens* (80/20 *Ni*/*Cr*) *used in the creep test.* (*A*) *coated with ceramic N* 143; (*B*) *as* (*A*) *after* 100 *hr. at* 1975° *F and* 600 *lb. per sq. in. stress*; (*C*) *uncoated specimen, test conditions as for* (*B*). *Platinum extensometer attached to each specimen.*

In instances where production of goods requires clean air, such as in certain painting or lacquering operations, air filtering has to be applied. In a subsequent article air filters and their use in metal finishing will be dealt with.

(*To be continued*)

Bibliography

"A Guide to Current Practice." Inst. of Heating and Ventilating Engineers, London. 1955.
Faber, Oskar. "Heating and Air Conditioning of Buildings." Architectural Press, London. 2nd Edition.
"Handbook of the Fan Engineering Industry." Fan Manufacturers' Association, London, W.C.1.
"Fans Terms, Definitions and Standards in Use." Fan Manufacturers' Association, London. 1948.
Osborne, W. C., and Turner, C. J. "Woods Practical Guide to Fan Engineering." Woods of Colchester Ltd. 1952.
B.S. Code of Practice 352: "Mechanical Ventilation".
Dalla Valle, J. M. "Exhaust Hoods." Industrial Press, New York. 1952.
"Ventilation of Factories and Workshops." Welfare Pamphlet No. 5. H.M. Stationery Office.
The Factories Acts 1937 and 1948. H.M.S.O.

FINISHING

NEWS REVIEW

Fulmer Research Institute Celebrates Tenth Anniversary of Foundation

ENCOURAGING RECORD OF RESEARCH PROGRESS

TEN years have passed since the day in 1947 when the late Sir Stafford Cripps opened the Fulmer Research Institute at Stoke Poges, Bucks. And in that time, because the parent company, Almin Ltd., has consistently ploughed back profits, the investment in the form of new buildings and equipment has been doubled.

The Institute was founded to serve British industry, and sponsorship from this source has grown steadily throughout a decade, particularly in the field of testing, analysis, and short-term investigations. But only about a quarter of the work undertaken by the laboratory is derived from this source, twice as much again being devoted to research on behalf of government departments and the nationally-owned undertakings. In addition, there has been a marked increase recently in work sponsored by both the United States government and American industry, and the present value of dollar contracts exceeds $120,000.

The Fulmer research establishment provides an opportunity for the firm too small to afford its own laboratory, but enterprising enough to realize the need for scientific development, to conduct research along lines of its own choosing.

Developments in Atomic Energy

Developments in atomic energy have been reflected in the increased amount of work that has taken place on uranium, titanium, zirconium, vanadium, niobium and hafnium in the current programme. But still of outstanding importance is the work that is being done with aluminium and its alloys, although these are now giving way to the "new" metals.

During the past 10 years, nearly 700 British firms have submitted technical problems to the Institute. Many of these have been of a routine nature and some have been concerned with service failures and important short-term investigations. But the major effort in this period has been expended on some 115 long-term research projects of which about 30 are still in progress at the present time. Most of the problems have been of a metallurgical character.

Of the major research projects undertaken, some of the most important have been concerned with silicon-aluminium steels, aluminium-tin bearings, ceramic coatings and aluminium alloys.

Investigation of the silicon-aluminium steels and the ceramic coatings have formed part of the research programme on high-temperature materials for possible jet-engine applications. As effective as the expensive stainless steels in resisting oxidation at high temperatures, with the added advantage that there is no need for strategic alloying additions such as nickel, these materials should be attractive for such uses as heat exchangers.

The development of low-emmissivity coatings bonded to high-temperature materials can reduce the radiant-heat pick-up in, for example, the flame tubes of gas turbines, to permit higher operating temperatures.

Extensive development work is being carried out on a pilot-plant scale to produce aluminium of high purity by a method involving the direct thermal reduction of bauxite, and a new process for the extraction of titanium has been developed on a laboratory scale.

The director of the Institute is Mr. E. A. G. Liddiard, M.A., F.I.M.

I.M.F. LAYOUT COMPETITION PRIZEWINNERS

In an interesting competition organized recently by the Midlands Branch of the Institute of Metal Finishing entrants were asked to submit a layout diagram for a plating shop of given dimensions and incorporating certain specified processes. From an entry of encouragingly high standard the first prize of £50 was shared by Mr. P. Berger and Mr. K. S. Dean, who with the winner of the £10 third prize, Mr. D. K. Blizard, are seen below with Mr. R. A. F. Hammond (*right*) president of the I.M.F., after the prizegiving ceremony.

TECHNICAL AND INDUSTRIAL APPOINTMENTS

Two special directors recently appointed to the board of Amber Oils Ltd. are Mr. V. E. Baker (as commercial director) and Mr. E. G. Reynolds (as works director).

Mr. V. E. Baker has been with the **Amber Group of Companies** for nine years in various capacities, having been engaged in the oil and chemical trades for over twenty years, nine of which were spent with Thomas Hedley and Co. Ltd. Mr. E. G. Reynolds has also been with the Amber Group of Companies for nine years, having been engaged in various engineering appointments over a period of twenty-two years, after serving his apprenticeship with the Austin Motor Co. Mr. Reynolds is an Associate Fellow of the Institute of Petroleum.

* * *

A member of the Simms Group and manufacturers of the well-known "Airflo" products including fans and ventilators, the **Industrial Fan and Heater Co. Ltd.,** Birmingham 11, announce that Mr. W. H. Dudley has moved to the firm's Swansea office at 256 Oxford Street as manager. Mr. Dudley has been closely identified with "Airflo" products for several years and will be available for advice on all aspects of industrial ventilating and heating.

Study Group for "Cermets"

THE board of directors of the American Society for Testing Materials at a recent meeting approved the formation and personnel of a study committee in the field of cermets—the group of materials combining properties of ceramics and metals which show such great promise in high temperature and abrasive environments. The authorization was the result of a conference held in November, 1956, with representatives of several fields of activity present, including A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys; Committee B-9 on Metal Powders and Metal Powder Products; Committee C-21 on Ceramic Whiteware and Related Products; Committee C-22 on Porcelain Enamel; and the Joint Committee on Effect of Temperature on the Properties of Metals. Each of these groups and others have an interest in this field.

The conference revealed that at present practically all of the materials produced as cermets are made for experimental usage with no type being made by more than one manufacturer. The committee will endeavour to promote information on the subject in the form of papers, meetings and symposiums. Its first problem will be the study and observation of the commercial progress in order to know when test methods and product standards are desired.

It is expected that the study committee will be developed into a permanent group to serve in an advisory capacity to A.S.T.M. technical committees. Its immediate objective will be to review the whole broad field of "cermets" including improved terminology and the classification of the various aspects of the entire field from the standpoint of A.S.T.M. activities.

WORKS RE-ORGANIZE

WITH their re-equipped premises at 42 Lower Loveday Street, Birmingham 19, Horwitch Smith and Co. Ltd. have concentrated the whole of their activities in the one works.

The Birmingham works can now give demonstrations of the Knapsack-Griesheim Whirl Sinter Equipment, the flame spraying of all types of polymers, the spraying of P.V.C. spraysols and the dip applications of P.V.C. plastisols and plexigels.

COURSE CHANGES TITLE

THE City and Guilds of London Institute, Gresham College, Basinghall Street, London, E.C.2, have announced that the title of the scheme previously known as the Technology of Pigments, Paints, Varnishes and Lacquers has been changed to Paint Technology and the two grades will now be known as Intermediate and Advanced; the Operatives' Course remains unchanged.

The regulations for the Advanced examination have been revised and now include both specified practical work and a practical examination. The new scheme will be introduced with the 1958 examinations, but examinations on the old scheme will be held in 1958 and 1959 in addition to this.

The following examinations will therefore be held in 1958:

(*a*) Paint Technology—Operatives' Course.
(*b*) Paint Technology—Paint Technologists' Course—Intermediate and Final (Old Scheme).
(*c*) Paint Technology—Technical Service Representatives' Course—Intermediate and Final (Old Scheme).
(*d*) Paint Technology—Intermediate and Advanced (New Scheme).

CARDIFF FIRM GETS GERMAN ORDER

A CARDIFF firm, Edward Curran Engineering Ltd., have received an order for a Curran continuous automatic degreasing, pickling and drying plant from Wurttembergische Metallwarenfabrik of Geislingen/Steige in Germany. This well-known German company has been established for over a hundred years and are renowned for the high quality of their products which include a great variety of electro-plated and silver-plated domestic and table ware.

I.S.M.E. then (S.A.S.M.U.T.A.) made a tour of this Works in 1955.

Extending over an area of 40 acres, the firm now employs about 5,000 people and are continuing their policy of installing the best and most modern plant available for their various production lines. The Curran plant is to be installed for treating heavy high-quality hollow-ware, prior to vitreous enamelling.

The cost of the plant is in the region of £27,000 and will be designed and built at the Curran factory in Cardiff. It is expected to be installed in January, 1958, after direct shipment by continental wagons from Cardiff to Geislingen.

OPEN DAYS AT THE C.R.L.

THE Chemical Research Laboratory, Teddington, Middlesex, is holding a series of open days, beginning October 1 and ending two days later, to show the work that is being done there.

Applications from firms for invitations should be sent to the Director indicating whether a morning or afternoon session is preferred. An afternoon session only is being held on the first day.

Firms already on the mailing list need not re-apply.

THE INSTITUTE OF VITREOUS ENAMELLERS Annual Conference

Chester, October 3 & 4, 1957

THE Annual Conference of the Institute of Vitreous Enamellers will be held this year at the Grosvenor Hotel, Chester, on October 3 and 4.

On the first day of the meeting delegates assemble in the morning at the Grosvenor Hotel for transport to visit the works of John Summers and Sons Ltd., at Shotton, where the day will be spent, by kind invitation of the directors of that company, in inspecting the manufacture of steel, the rolling of sheet and strip, and the production of nickel- and zinc-coated steel sheets.

On the second day, after the Annual General Meeting, a number of technical papers and contributions will be presented and discussed, the subjects including Steel Sheets for Vitreous Enamelling, Observations on Abrasion Resistance of Vitreous Enamels, Electrostatic Spraying of Vitreous Enamels, Enamelling of Aluminium, and a contribution from the French Institut de l'Email on Architectural Applications of Enamel.

The Institute Annual Dinner and Dance will close the Conference.

Arrangements have been made for a ladies' visit to Chirk Castle, Denbighshire on October 3.

Harrogate Industrial Film Festival

THE first "Festival of Films in the Service of Industry" will be opened officially by the Rt. Hon. Lord Mancroft at Harrogate in October. Presiding will be the Festival's president, The Rt. Hon. Lord Godber.

The festival will continue for four days until Saturday, October 12, when awards will be presented at a Majestic Hotel dinner where the principal guest speaker will be Dr. Charles Hill, M.P., Chancellor of the Duchy of Lancaster. Special arrangements are being made to fly Dr. Hill to Harrogate from Brighton where he will be attending a political meeting.

Lord Godber has announced that detailed planning of the festival is now well advanced and panels have been kept busy viewing more than three hundred films in ten categories which have been submitted for exhibition. Many distinguished representatives of industry have accepted invitations to act as chairmen or to speak at the various sessions.

In addition to the British films which have been selected to compete for awards there will be a number of foreign films participating on a non-competitive basis.

INDUSTRIAL SAFETY CAMPAIGN

A NATION-WIDE campaign with the slogan "guard your hands" is being organized by the Royal Society for the Prevention of Accidents.

Each year the society organizes a safety week when special attention is directed to the reduction of industrlai accidents. The society says that there is ample proof that these and other activities not only do much to reduce accidents, but, by saving valuable production hours, contribute to the general prosperity of the community.

In selecting the theme for the 1957 campaign the society was influenced by the large number of accidents that occur every year to persons engaged in handling goods. For example, in 1955, the last year for which full records are available, no fewer than 44,613 persons were involved in handling accidents in factories alone. When it is considered that this represents almost a quarter of the total reportable factory accidents for all causes, the full extent of the problem can be appreciated.

The "guard your hands" campaign will be directed mainly at managements, and a comprehensive range of publicity material has been prepared.

Appointment of Agents

AGENCIES in three areas of Britain have been awarded by Taylor Tools and Supplies Ltd., Vortex Works, Atalntic Street, Broadheath, Altrincham, Cheshire, who specialize in grinding and polishing equipment. In the Midlands, H. Sumner Ltd., 45-47 Stour Street, Birmingham, 18, has been appointed. In Lancashire, Cheshire and North Wales an agency has been given to Mr. G. Clarke, 64 Beverley Road, Manchester 14, and for London and the Home Counties, Power Tools and Accessories Ltd., 37 Sheen Road, Richmond, Surrey, have been appointed.

* * *

THE world distribution of Amber Oils Ltd. pressurised dispenser products, "Aerozene" (penetrating oil and spring lubricant), "Blink" (invisible metal protector), and "Rusolvent" (easing fluid), have now been taken over by Slip Products and Engineering Co. Ltd., 34 Great St. Helen's, London, E.C.3, and St. Albans. "Ambersil" (Silicone mould release and anti-stick agent), and "Ruby" (industrial protective lacquer), will continue to be handled by Amber Oils Ltd.

AWARDS FOR LONG SERVICE

A DAY early last month was a momentous one for 233 employees of Keith Blackman Ltd., the London firm of fan engineering equipment and industrial gas equipment factors.

The lucky ones were those with 25 years continuous service or more with the firm, and their reward—an inscribed wrist-watch. Of almost two thousand employees, 233 qualified for the award; in fact, the total service of all the firm's employees totals more than 7,700 years, a very creditable record in these days of fluctuating staffs.

About two-thirds of the presentations were made by the chairman and managing director, Mr. D. S. Woodley, at the Tottenham works, and most of the remainder were presented at the Arbroath works by the works manager, Mr. W. G. Calder.

NEW COMPANIES

"Ltd" is understood, also "Private Co." Figures = Capital, Names = Directors, all unless otherwise indicated.

MIDLAND METAL SPRAYERS LTD., Coombs Road, Halesowen, Worcs. May 6. £1,000. *H. Nock, K. D. Hicks.*

CRAUFURD STAINLESS STEEL CO. LTD., 6 Brackenbury Road, London, W.6. May 6. £2,000. *F. R. McNally, G. C. Bath.*

BROOK BROS. LTD., 70/72 Eyre Street, Sheffield. May 14. £100. *To carry on bus. of chromium, electro and nickel and metal platers, etc. W. Turner, R. W. Nicol.*

A. J. BAILEY AND SON LTD., 53 Tenby Street, North, Birmingham 1. May 22. £1,000. *To carry on bus. of silversmiths and electro plate manufacturers, enamellers, etc. B. O. Bailey and Mrs. A. J. Bailey.*

TUBEMAN STAINLESS LTD., 5 Ossian Mews, Stroud Green, N.4. May 22. £1,500. *To carry on bus. of steel makers, etc. Mrs. K. Heath, D. J. MacMillan.*

ELECTRO BRUSH PLATING LTD., 125 King Street, Maidenhead. May 29. £3,000. *To carry on bus. of nickel platers, etc. M. P. Hewland and Mrs. J. W. Hewland, D. W. Everitt.*

ANTI-CORROSION TREATMENTS LTD., 28A Widmore Road, Bromley, Kent. June 7. £2,000. *D. W. Bass, K. E. Bass, L. N. Sinclair.*

DUALIT PLATING LTD., 18-22 Fenarth Street, Ilderton Road, S.E.15. June 13. £100. *To carry on bus. of typewriter specialists, repairers, rebuilders and part makers, anodisers, oxidisers, etc. M. Gort-Barten and Hannah R. Gort-Barten. C. T. Grant and Maud J. Grant.*

EVERLASTING CONSTRUCTION CO. LTD., 44 Corn Street, Bristol 1. June 18. £12,000. *To carry on bus. of buyers, sellers, holders, treaters and dealers in structural and other steel, etc. R. Hill, J. V. Onslow.*

HUNTING ENGINEERING LTD., Luton Airport, Luton, Beds. June 20. £100,000. *To carry on bus. of mechanical, structural, electrical and nuclear engineers. K. D. Morgan, P. L. Hunting and W. A. Summers.*

From the Register compiled by Jordan & Sons Ltd. 16, Chancery Lane, London, W.C.2.

PRESTON PLATING AND ENGINEERING CO. LTD., 60 Frith Street, London, W.1. June 27. £1,500. *G. N. Preston and Mrs. L. R. Preston.*

HENRY HYDE AND SON LTD., Britannia Brass Works, Hill Street, Ashton-under-Lyne, Lancs. June 28. £2,500. *To carry on bus. of brass-founders, finishers, general engineers, etc. F. W. Hyde, Mrs. D. Hyde and H. F. Hyde, Mrs. D. F. Smithies.*

LYE TRADING CO. (TINPLATE) LTD. July 1. £10,000.

JOHN G. FENTON AND CO. LTD., 2 Prebend Street, N.1. July 8. £100. *To carry on bus. of engravers, chasers, enamellers, lacquerers, platers, sheet metal workers, etc. Kathleen E. Fenton and E. W. C. Flavell.*

D. AND A. ELECTRO PLATERS LTD., 15 Whitehorse Road, West Croydon, Surrey. July 8. £6,000. *H. D. Doulton, F. R. Adams.*

WELDING AND METALCRAFT SERVICES LTD., 1389 London Road, Norbury, London, S.W.16. July 8. £1,000. *D. T. S. Wilson, Elsie I. Allen.*

TRADE and TECHNICAL PUBLICATIONS

"Metal Degreasing by Trichloroethylene": Since Imperial Chemical Industries Ltd. introduced the trichloroethylene process more than twenty-five years ago, industry has had a speedy and efficient metal degreasing process available that can be adapted to suit almost any type of work, provided the contamination or its adhesive is soluble in "trich". The whole cleaning operation is completed in one plant, from which the work emerges in a dry, neutral condition ready for subsequent processing.

This booklet introduces the methods of treatment, which vary according to the type of work and the nature of the contamination. Tables at the back list plant design particulars, average performance data for gas-, steam-, and electrically-heated plants, and the safety precautions essential in using the chemical.

"Instantair Couplings": The B.E.N. Patents Ltd., High Wycombe, Bucks, "Instantair" couplings are described in a leaflet, CB.158, issued recently.

These couplings, tested and approved by the National Physical Laboratory up to 10,000 lb. per sq. in., are already well-known to industry. The leaflet lists the reference numbers and thread sizes of the couplings together with a small table giving flow data with a line pressure of 90 lb. per sq. in.

"Oxythene": This is the name of a new bulletin which Horwitch Smith and Co. Ltd., 42 Lower Loveday Street, Birmingham 19, are issuing to describe their Oxythene Duoply laminated ducting made in P.V.C. material.

The ducting is now available in a complete range of sizes and types which are listed in the brochure. The sections are prefabricated for easy erection, but the firm also maintains a staff of heating and ventilation engineers who are able to design, build and install a plant from start to finish. The brochure is available on request.

"Modern Dust Collection": A revised edition of an earlier issue of this brochure has now been issued by The Visco Engineering Co. Ltd., Stafford Road, Croydon.

The publication is well-illustrated and produced. It describes the problems that dust collection poses to many industries and the methods that can be used to solve them.

In some trades the dust collected is of no value, but more often it is a valuable by-product which can yield a handsome profit. In some cases material has to be handled in the form of dust at some stage of manufacture, and efficient collection of the product in the form of powder is an important part of the actual manufacturing process. Then again, the danger to health of uncontrolled dust has been fully recognised by the stringent regulations on the subject in the latest Factories Act.

An addition to the revised edition is the table of typical dimensions and capacities which is supplied for preliminary planning purposes only.

"Continuous Spray Pickling and Washing Plant": Pickling is a necessary process prior to vitreous enamelling, galvanizing, plating and other finishes, and also for the removal of oxide and scale after hot rolling and annealing.

This leaflet describes an alternative to the open vat method which has been developed by the Edward Curran Engineering Ltd., Process Plant Division, Cardiff, Glam.

In the Curran process, spray jets bring the acid solution to the work, and by means of a three-phase action combining the chemical action of the acid, the mechanical force of the jets and the aeration effect of the spray, an accelerated attack is made on the oxide or scale, thereby shortening the pickling time required. A sectioned drawing and abbreviated description of the plant is given in the leaflet.

Latest Developments in PLANT, PROCESSES AND EQUIPMENT

Ball Mill Container in Rubber/Resin Compound

A NEW type of rubber container, ancillary to the existing range of ball mills for handling hard and abrasive materials, and, also, for use as a barrel for burnishing and polishing small metal parts, has been announced by the Pascall Engineering Co. Ltd., 114 Lisson Grove, London, N.W.1. The sizes available are nominal 2-gallon, 1-gallon and ½-gallon.

The new container is made of "Fortiflex", a chemical combination of rubber and synthetic resin developed by The Dunlop Rubber Co. Ltd. and a material with the desirable properties of toughness and lightness, rigidity and flexibility and resistance to wear and corrosion.

Fig. 1 shows the construction of the container which is made up of an open-ended drum to which two solid rubber tyres are welded. The open end is closed by means of a soft rubber ring which is tightly compressed between two metal plates, the interior metal plate being coated on the inside with rubber to make an all-rubber interior to the container.

Around the neck of the container there is a metal ring fitted with metal lugs, positioned to face the outer metal plate, which has three notches to allow latching of the plate in the bend of the lugs. A clamping screw brings the two metal plates together compressing the sealing ring against the wall of the container which is kept rigid by the outer metal ring, ensuring perfect sealing of the container.

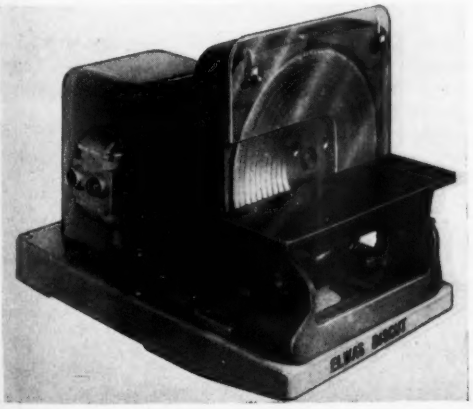


Fig. 1. Ball mill container.

Disc Filing and Trimming Machine

A NEW machine for filing and trimming all the softer materials from mild steel to rubber is being manufactured by Printac Ltd., Rawden Mews, Cardiff. (Fig. .2)

It is a disc filing and trimming machine known as the Elwas-Discut. Rapid in operation the machine cannot clog, imparts a fine surface finish to the material and can work to fairly close limits.

The work-rest measures 4 in. by 11 in. and the drive is supplied by a ½-h.p. motor. Discs can be supplied separately for independent mounting if required.

Self-adhesive Tape

AN addition to their range of Permacel self-adhesive tapes has been made by Johnson and Johnson (Great Britain) Ltd., Slough, Bucks.

Fig. 2. Disc filing machine.

This is known as "Fine Grade" paper masking tape and has been produced to meet the requirements of those users who prefer a tape with a backing material of thinner section.

The advantages claimed for this new thinner tape are that it gives a lower build-up of paint at the edge, which is of particular value in air-dried spraying work where forming and moulding qualities are called for. The new tape is available in 60-yard rolls in widths of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, 2 and 3 in.

Enamel Paint

THE latest product to be announced by Paripan Ltd., 1 Sherwood Street, Piccadilly Circus, London, W.1, is "Par-Exel," an industrial low-bake high-solid content white enamel. The company reports that the introduction of automatic techniques to paint manufacture has enabled them to reduce considerably their manufacturing costs so that they are able to market this new product at a remarkably low price.

"Par-Exel" is suitable for all modern processing techniques, including electrostatic application, infra-red stoving, etc., for convection stoving, temperatures of 220°-250° F are used for times of 20-40 minutes.

The product is available in 5-gallon drums only and in either natural white or blue-white. Free pint samples and thinners can be obtained on application to the manufacturers of this new enamel, which is already finding application in many industries including domestic appliance, hardware and electrical fitting manufacture.

Corrosion Inhibitor

A CONSIDERABLE amount of interest has centred recently on the possibility of using tannins as inhibitors of metallic corrosion and a certain amount of investigational work is currently taking place into the mechanism of their action.

A new product for the preparation of rusted surfaces prior to painting, which involves a tannating process has recently been introduced by the Plus-Gas Co. Ltd., 1-11 Hay Hill, London, W.1.

Application of this material, known as Plus-Gas Formula E External Metal Treatment to a metal surface is said to produce a tannate/gamma ferrous oxide complex by reaction between the tannins and the oxide film. This gives rise to an insoluble corrosion-resistant film which is claimed to resist the effects of the weather for a number of days even in exposed conditions. Under cover the coating will remain intact for several months and inside buildings under normally heated and ventilated conditions it should last indefinitely.

Being an integral part of the metal surface the tannin film is said not to chip or flake and to afford an effective bond for subsequently applied coatings preventing the formation and spread of rust under a paint film even when damaged. The product is non-acid and non-toxicant.

Plastic Tank-lining Process

CORROSION Ltd., 16 Gloucester Place, Portman Square, London, W.1, have announced a new technique for the lining of process and storage tanks with plastic of various types *in situ*. The technique is claimed to be an advance on previous practice in many respects.

The process has been developed by Corrosion Ltd., in conjunction with the specialist firm of contractors, Colrate Limited, London, who are responsible for the preparation of the surface, application and curing of the linings made by Corrosion Limited.

A dust-free method of shot-blasting the work-surface by vacuum machine is used, after which the application of a plastic lining and its heat-curing to give a hard, durable, tightly adhering, chemical-resisting and inert film, are carried out.

An interesting aspect of this process is that it has been found possible to re-line tanks with the minimum of interference with production. This is a valuable feature since the cost of removing a tank and of the consequent interruption of production often involves an expense greater than the cost of the re-lining process itself.

Spray Gun with a Wide-Angle Cap

A NEW "Aeraspray" spray gun has recently been introduced by Aeraspray Association Ltd., Nechells, Birmingham 7, which has a wide-angle aircap to produce the spray pattern shown in the illustration. (Fig. 3.) This differs fr m the conventional pattern by being parallel for its total length, which results in an evenness of cover usually impossible with an elliptical shape, and it is claimed that this eliminates runs.

A high speed of working is possible because it is not necessary to overlap consecutive patterns and the full width can be utilized. The thirteen holes in the aircap give very good atomization and produce a finish of the type usually considered to be commercially perfect without any flatting.

The gun is primarily intended for large articles and is designed for use with a pressure feed container to give a spray width of 30 in. and a proportionally high production rate. It is built on a one-piece body and handle forging of Duralumin which cannot twist out of alignment, and all wearing surfaces are bronze bushed.

Fig. 3.—Spray gun and pattern.